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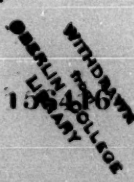

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THE VENTILATION OF PASSENGER CARS ON RAILROADS.*

BY DR. CHAS. B. DUDLEY,

Chemist to the Pennsylvania Railroad Company, Altoona, Pa.

I dare say every one who has spent any time in a railway car has wondered to himself why in the world the railroad company does not ventilate its cars better. The query is a very natural one, but I am sure if the general public knew how much the subject of the ventilation of passenger cars on railways has been studied, and how difficult are the problems presented, they would be more lenient in their criticisms than they sometimes are.

Of course, the first step in the study of a problem of this kind is to find out what is the present state of affairs. Professor Ripley Nichols, of the Massachusetts Institute of Tech-

*A Lecture delivered before the Franklin Institute, Friday evening, January 22, 1897.

nology, some fifteen or more years ago, made a number of analyses of the air from railway cars on the Boston and Providence Road, for the Railway Commissioners of the State of Massachusetts. Also, about fifteen years ago, a system of ventilation of passenger cars was developed by a gentleman who had so much influence back of him that he had a car constructed which was sent to Altoona by the officers of the Pennsylvania Railroad, with instructions to make such experiments as would demonstrate whether that car was better ventilated than the standard passenger car of the road. In connection with the experiments on that car we made analyses of the air from passenger coaches three times; that is, of three different samples. The results obtained both by Professor Nichols and ourselves indicated that the present passenger coach on most of the railways of the country gets into it and out again—which practically constitutes ventilation—somewhere from one-eighth to possibly a tenth as much fresh air per hour as it ought to get. It is rather interesting that Professor Nichols' analyses and our own very closely coincide; and it is also quite interesting to know that Professor Nichols analyzed the air from smoking-cars and found no greater amount of carbonic acid in the air from these cars than from the ordinary passenger coach. I am not aware that any analyses have ever been made of the air of Pullman coaches.* Still further, two or three years ago we spent nearly the whole winter with a passenger coach on the Pennsylvania Railroad, trying to study and develop a system of ventilation.

Notwithstanding this study, and notwithstanding the amount of effort and the cry that is in the technical papers, and sometimes in the daily papers, in regard to the ventilation of passenger cars, I am very sorry to have to say to you, frankly and honestly, that it is not possible at the present time to properly ventilate a passenger car on a railway. No system

*Since this lecture was delivered, a note from Wm. Forsyth, Mechanical Engineer of the C., B. and Q. R. R., calls attention to the fact that the air from Pullman cars has been analyzed, the results obtained being given in the Proceedings of the Master Car Builders' Association for 1894, pages 234-241.

is at present known by which this can be successfully accomplished. If I succeed in what I have attempted to-night, you will, before I am done, understand why.

Perhaps I may best bring out what I have in mind by asking myself a series of questions and then answering them for you. Accordingly, the first question which I shall ask myself is, what is the problem that we are undertaking to solve when we attempt to ventilate a passenger car? It is, perhaps, not too much to say that no problem in engineering has ever been undertaken by mechanical engineers, or ventilating engineers, if you choose, or chemists, or scientific men, that is so fraught with difficulties as the ventilation of passenger coaches on railroads. Let us see what the problem is.

An ordinary passenger coach contains about 4,000 cubic feet of space—about one-fifth the size of this room, as near as I can estimate. It is proposed to take into this small space at least sixty persons; to keep them in this space continuously, without allowing them a chance to get out, for four hours or longer; to keep these persons warm enough for their comfort in winter, and to supply them with enough fresh air to ventilate the car properly, and at the same time exclude, throughout the year, smoke and cinders, and, in the summer season, dust. I think it is fair to repeat that no problem has ever been committed to the experimental and mechanical engineering departments of the Pennsylvania Railroad since I have been connected with it, now a little over twenty years, so difficult of solution as this problem of car ventilation.

The next question I shall ask myself is, is a system of ventilation on passenger cars essential throughout the year? Do you need to ventilate your cars in summer? Why not open your doors and windows and have all the fresh air you want? This seems, possibly, a very satisfactory solution of the problem, and if one state of affairs could be brought about, which, however, we cannot control, there would be no necessity for anything more than a system of ventilation in the winter season. That state of affairs is this: If the wind always moved at right angles to the direction of the train, you would have no difficulty, for the smoke and cinders and dust would

then always be blown away from the cars, and doors and windows could be left open at pleasure. But the wind does not always blow crosswise to the direction of the train, and sometimes there is no wind at all, so that it frequently results that the motion of the train itself brings the smoke and cinders directly from the locomotive back to the coaches. Still further, on roads using dirt or gravel ballast, the amount of dust in the air is sometimes something appalling. In reality, therefore, our problem is to provide a system of ventilation that in the summer season will exclude dust, in the winter season will warm the air properly, and throughout the year will keep out smoke and cinders. We must, therefore, study the problem both from the summer and winter standpoint.

Again, can we have a ventilating system apart from the heating system? I answer that in the course of the years that this problem has been before the experimental departments of the Pennsylvania Railroad, we have been called upon to investigate a number of different systems. It apparently seems to many who have not studied the problem sufficiently, that it is only necessary to make a hole in a car and let the fresh air in, and you have a system of ventilation. Some of the systems that we have examined have practically been very little more than this. The present system of ventilating Pullman cars consists simply in letting cold air into the car through the deck sash near the top of the car, which cold air mixes with the warm air in the car, and may pass out through the ventilators over the lamps, or possibly out through the deck sash on the other side. Other so-called systems simply put ventilators in the deck to draw air out of the car, allowing it to find its way into the car as best it may. It is, perhaps, hardly necessary to say that such attempts can hardly be regarded as worthy of the name of a ventilating system. To our minds, the first requisite, the first essential feature of a system of car ventilation in our climate, is the heating system. There is very little use, if we are right, in trying to study the problem without studying the two systems together. Accordingly, in all our studies, we have tried to develop the two systems in connection with each other, and our belief is that any system of ven-

tilating passenger cars that does not warm the air that is taken into the car, will result in failure. No human being can endure to have the amount of fresh air required for successful ventilation taken into a car in winter, unless that air is warmed.

Just here another interesting question arises, viz.: what is the test of good ventilation? How do you know when a room, or a car, if you choose, is well ventilated? It is obvious that we must have some measure of the ventilation, or else we cannot tell whether we are taking too much or too little air into the car. We have followed, in the studies which we are putting upon this question of the ventilation of passenger cars, Parke's Practical Hygiene, which, as we understand it, is the standard on hygiene for the British army. The seventh edition gives, perhaps, the best summary now available of the information we now possess, on the general subject of ventilation. In this edition it is stated as a test of good ventilation, that any space, be it a room, a passenger car, a theatre, or whatever you choose, is well ventilated when a person coming into that space from outside fresh air detects none of the odor characteristic of badly ventilated spaces. But what measure have we of what is characteristic of no odor? Odors cannot be measured. Fortunately, however, one at least of the substances accompanying the odor characteristic of bad ventilation, and which is proportional to the odor, can be measured.

Let me see if I can make this clear. Three things are continually given off from our bodies, namely, carbonic acid, water vapor and organic matter. Every time we breathe, we breathe out some carbonic acid, we breathe out some water vapor, as every one knows who has been out on a cold morning, and we also breathe out, there is exhaled from our bodies, a certain substance, which, for want of a better name, is simply called organic matter, and which is believed to be the source of the odor. Of these three substances, carbonic acid is easily measurable. That is the substance we measured when we made analyses of the air in the cars, or that Professor Nichols measured in his analyses, and it is customary to take the amount of carbonic acid in the air as the measure of good ventilation.

Many years ago, before this latest test that I have already

mentioned here to-night was introduced, it was customary to place an arbitrary limit on the amount of carbonic acid that should be allowed in the air, in spaces which were said to be well ventilated. That is to say, twenty years ago, if the amount of carbonic acid in the air in any given space did not exceed 10 cubic feet in 10,000 of the air, that space was said to be well ventilated; but later studies have changed this view. A very large number of analyses of air have been made to find the amount of carbonic acid that is characteristic of the air when you can just begin to detect an odor. In this book which I have here, Parke's Practical Hygiene, there is given a summary of a very large number of such analyses, giving the amount of carbonic acid that is in the air when one can just begin to detect an odor. The average of these analyses indicates that when two parts, or 2 cubic feet of carbonic acid that comes from our bodies, or the bodies of animals, in 10,000 of air is found, one can just begin to detect an odor in a closed inhabited space. Therefore, 2 cubic feet of carbonic acid given off by human beings or animals in a closed space, in 10,000 cubic feet of air, is taken as the test or measure of good ventilation. I should say for your information, perhaps, that the air in different parts of the world and from many different places has been analyzed a good many times for carbonic acid. From these it is found that there is a certain normal amount of carbonic acid in almost any air. The air in this room, even if the windows were wide open and the room vacant, would contain a certain small amount of carbonic acid. The average of these analyses (they vary somewhat)—in towns the amount is larger than it is in the country—but the average amount is about 4 cubic feet in 10,000; that is, 10,000 cubic feet of air contain normally 4 cubic feet of carbonic acid. Now, if we add to that the 2 that come from our bodies, we would find in what would be called a well-ventilated space an amount of carbonic acid not exceeding 6 cubic feet in 10,000.

Taking then this 2 cubic feet that comes from human beings as the measure of ventilation, we are prepared to take another step forward in our study of the problem. A good many experiments have been made by different investigators

as to the amount of carbonic acid that a human being gives off per hour. It has been found that men give off more than women; children less than either; that a man in vigorous work gives off more than a man in idleness; but the average of a mixed community—men, women and children, as they occur—is given as six-tenths of a cubic foot of carbonic acid given off from our bodies, both by the skin and from the lungs, per hour per person. So this is another of the foundations on which we are building up our scheme for the ventilation of passenger cars; namely, six-tenths of a cubic foot of carbonic acid given off by the average of persons from a mixed community such as we carry in our cars, per person per hour.

From these data it only takes a little arithmetic to get some sort of an idea of the answer to the next question which I am going to ask myself; namely, how much air per hour do we need to take into a car and out again in order to have that car properly ventilated? I will not make the calculation; but it is very simple. The data are, if 2 cubic feet of carbonic acid can be added to 10,000 cubic feet of air and still have good ventilation, how many cubic feet of air per hour must be brought into a closed space to bring six-tenths of a cubic foot per person down to a limit of 2 cubic feet in 10,000? If you made this calculation you would find this figure, viz.: that every hour after the first one, the first hour being occupied in saturating the space in which the persons are, 3,000 cubic feet of air per person per hour must be taken into any closed space in order to dilute the carbonic acid that is given off by an average from a mixed community down to the limit required for good ventilation, which is 2 cubic feet in 10,000, which again is the limit when an odor just begins to be perceptible to a person coming into any closed space where human beings are from the outside.

Now, let us take another step. 3,000 cubic feet of air per person per hour are required; but we have 60 people in a car, and 60 times 3,000 is 180,000 cubic feet of air, that must be taken into a car per hour, on the basis of this calculation which we have just made. What does that mean? It means that we must change the total air in that car forty-five times in an hour,

or about once in eighty seconds. I say to you very frankly that we have not attempted in our experiments to reach any such figure as this. When we came to get our foundations on which to start our experiments and noted this prodigious figure of 180,000 cubic feet of air per hour required, according to the theory of the best authorities in the books, that we ought to have in order to ventilate our cars well, we were simply appalled. It is practically out of the question to take that amount of air through a passenger car per hour, and I hope a little later to show you why.

I should say at this time, perhaps, that some two years ago experiments were carried on for some time, by a committee consisting of Dr. S. Weir Mitchell and Dr. J. S. Billings, the results of which were published by the Smithsonian Institution. The object of these experiments was to find out to what the drowsy feeling that we have when in an ill-ventilated place was due, and also to find out what produces death from lack of ventilation. Those studies seem to indicate that the amount of fresh air that I have mentioned, namely, 3,000 cubic feet of air per person per hour, is large, and that possibly a smaller figure would be satisfactory. These authorities, however, are very cautious; they give us no definite figures. They apparently could not prove the existence of, or at least could not isolate any poisons in the air that would produce death. They seem to indicate that the drowsy feeling is due principally to increase of carbonic acid and diminution of oxygen. And, finally, they say in so many words that it would be a mistake to assume from their experiments that the ordinary figures applying to ventilation are widely in error.

Now allow me while I ask myself another question. How much heat would be required to heat 180,000 cubic feet of air per hour from the temperature of zero, which is not at all uncommon in our winter here, up to a livable temperature in a car? I have spent some time over this query, but am compelled to utilize, however, the results of other people's experiments somewhat. The best information that I can get on the subject is that the heat from a pound of steam at a pressure of 15 pounds per square

inch is sufficient to heat 6,700 cubic feet of air from zero to 70° Fahrenheit. If we follow that through and find the amount of heat that would be required for a train of, say, twelve cars—which is not at all uncommon when traffic is good—we will be led to the result that it would take , in order to warm the air that would be required to ventilate the cars on the calculations that we have already made about 3 per cent. of the power of the locomotive; in other words, it would require about 400 pounds of steam per hour, and the locomotive of the largest type that is now on the Pennsylvania Railroad evaporates about 14,000 pounds of water an hour. This problem we have not met very seriously yet.

We do find, however, with some of the large passenger trains because of the speeds required to be maintained, that the drain on the locomotive is sometimes a little serious, especially when we are doing other things with the locomotive, such as running electric light plant in the baggage car. In the winter season, with six Pullman cars and trying to make high speed, it is sometimes difficult to maintain the steam pressure owing to this drain. The question of the amount of the heat required, however, is not one that ought to enter very strongly into our problem, because if we must have a large amount of heat to warm the air we must furnish it. That is all that can be said on this point. But it is certain that we could not warm twelve cars on the basis which we have been figuring, short of using from 3 to 3½ per cent. of the total evaporation of the locomotive, for heating purposes alone. Still further, I have in the above calculation simply planned to heat the air up to 70°; but as everybody knows, a car above the belt rail or 3 or 4 feet from the floor largely consists of windows, and there are constant leakages around these and the doors, so that it is probable that the air that leaves the heater system would have to leave it perhaps 10° and possibly 20° higher than 70°, on account of these leakages and on account of the large amount of heat lost by the glass. If we had to heat it 90° F., it would possibly take 500 pounds of steam per hour per train of twelve cars, and make a still further draft on the locomotive.

I said a few moments ago that in our experiments we had

made no attempt to get anything like so large an amount of air into our cars as 180,000 cubic feet an hour. We had a very careful consultation of the best experts we had on this subject before we began these experiments. I counselled this: "Let us not attempt to do more than half what theory calls for." A recent writer in one of the railroad technical papers calls for 60,000 cubic feet per hour, and wants to have it made by law requisite that every railroad car shall be provided with appliances that will give at least 60,000 cubic feet of air per car per hour, or 1,000 cubic feet of air per person. Just what will be the amount that we will ultimately be able to secure is still an unsolved problem, In most of the experiments we made two years ago, we worked on the basis of securing 90,000 cubic feet of air per car per hour.

I have had several drawings made, shown in Plates I and II, to give you, approximately, an idea of the state of the problem, Let me say that at present the only thing that can be called a system of ventilation in the passenger cars of the Pennsylvania Railroad consists in taking air in through a hood, shown at *a* in Plate I, which air passes down through a sheet iron pipe *b* and is delivered inside the casing *c* surrounding the stove *d*. A vertical diaphragm or partition *e f* divides the space between the stove and casing into two parts. The air is received at the bottom of this space, as is shown by the arrows, passes up one side of the partition and down the other, being heated by contact with the outside surface of the stove during this passage, and is then delivered to a trunk or box *g*, which extends nearly the whole length of the car. From this trunk, the heated air finds its way out through the registers *h h*, situated between the seats into the body of the car, and, finally, out into the open air, through the deck sash *i i*. Of course, also a small amount of the warmed air passes out of the ventilators over the lamps or gas jets. There are two stoves in each car, and two intakes for air, situated at diagonally opposite corners of the car. Several valves *j j* in the hood always secure the passage of the air down the pipe *b*, whichever way the car is moving. This system of warming and ventilating is known as the Spear stove system. A little study shows

that this system is open to two serious objections. These are, first of all, the stove. Everybody knows that we are trying to get rid of the stove for car heating, on account of the danger in case of accident. It is not necessary to say much about the deadly car stove. The newspapers do enough of that. Suffice it to say that one of the difficulties of the present system is the stove. The other difficulty is this, and a rather peculiar one it is: When the car is running and the wind is not too strong in the wrong direction, air is forced into the hoods, and thence into the car in the manner described, with the result that the car is fairly well warmed and ventilated. But when the car stands still, or when the wind in the opposite direction is just equal to the speed of the train, what takes place? The air goes in the other direction. The source of heat being higher than the outlets into the car, it is obvious that when the car is standing still, the air currents will move up through the pipe *b* instead of in the opposite direction, as is desired. And this is what we actually find to be the case.

Our studies have been concerned, however, principally with the ventilation of steam-heated cars. The constructions used I may explain, by reference to Plate II. The same hood *a*, on the top of the corner of the car, is used for an intake, as was the case with the Spear Stove System. The air entering this hood passes down through the pipe *b* into a space *c* below the floor, bounded by the floor, the false bottom, the outside sill and the first intermediate sill. This space is about 8 by 14 inches, and extends the whole length of the car. The heater pipes *d d* are situated above the floor in the same trunk that was used to carry and distribute the warm air in the Spear stove system. These pipes are filled with flanges as shown, to increase the surface. It is, perhaps, not necessary for me to go into the heating system further than simply to say that each side of the car has a certain amount of pipe of this kind, running the whole length of the car, which contains steam, of a pressure, say, of from 15 pounds down to no pressure at all, and even a vacuum. We use what is called the return system of heating; that is to say, underneath the car are two parallel pipes, one of which brings the steam from the locomo-

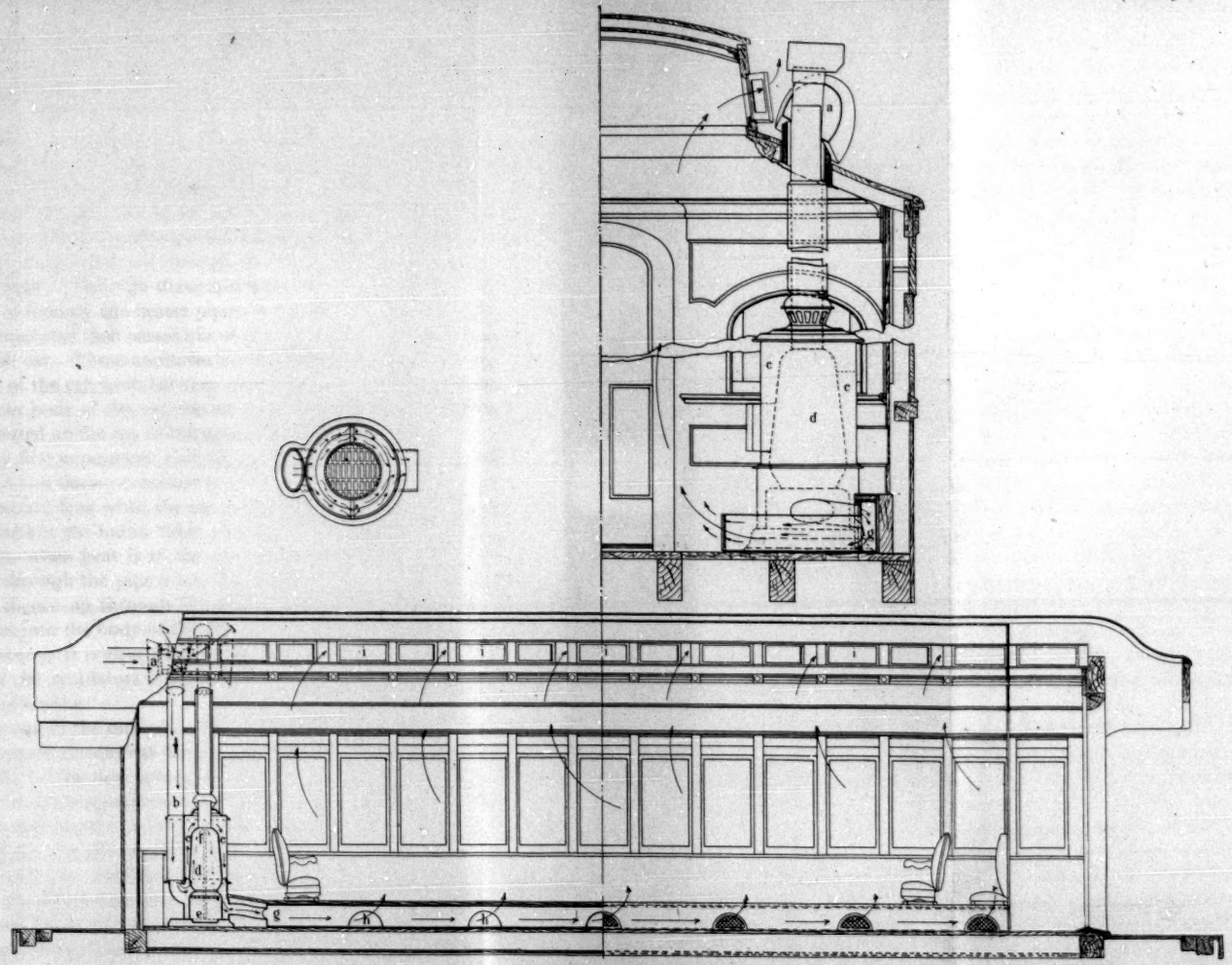

PLATE I.—SHOWING SPEAR STOVE SYSTEM OF HEATING AND VENTILATING PASSENGER CARS, NOW IN USE ON PENNSYLVANIA RAILROAD.

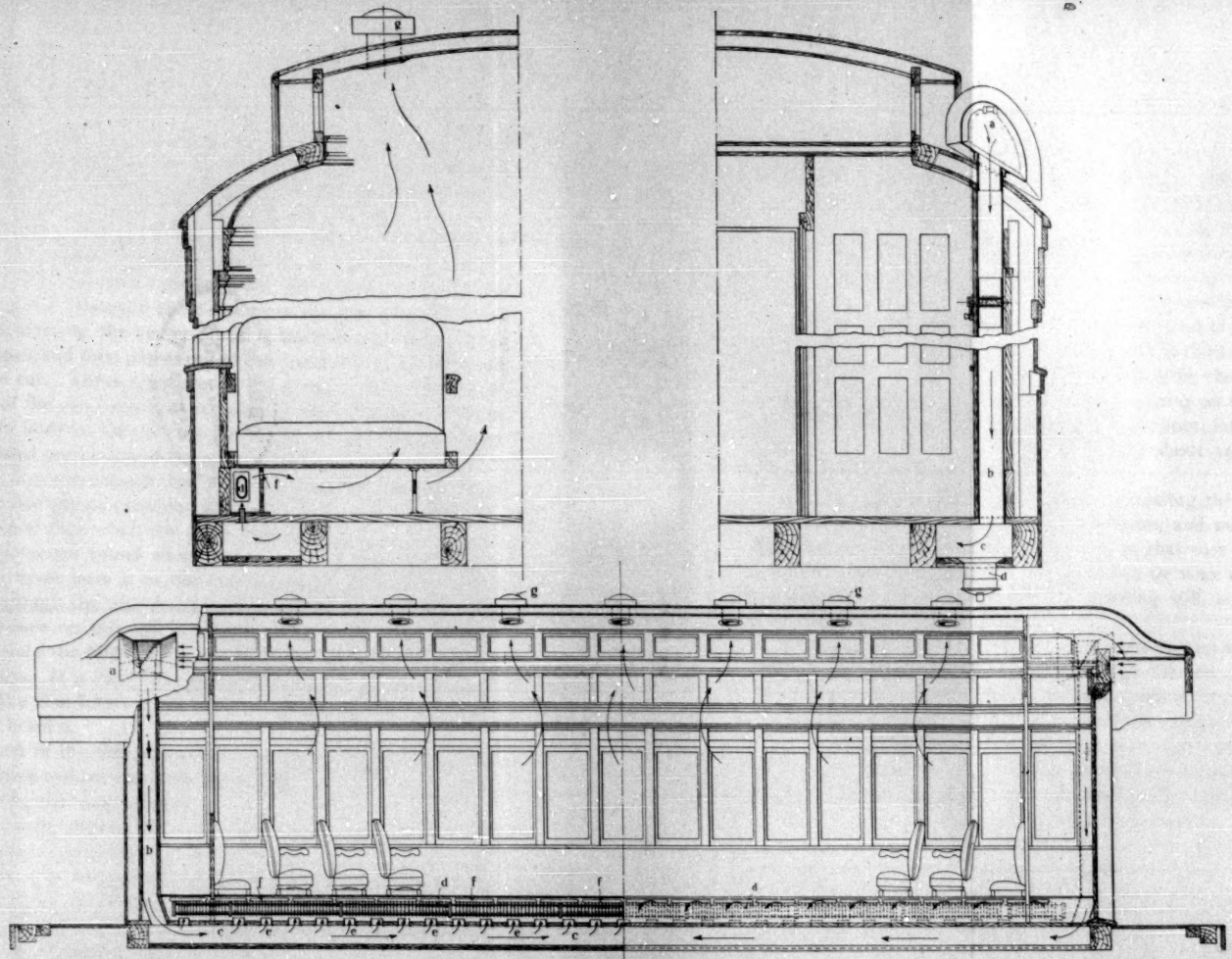

PLATE II.—SHOWING SECTIONS OF STEAM HEATED PASSENGER COACH ON PENNSYLVANIA RAILROAD, AS MODIFIED FOR EXPERIMENTS ON CAR VENTILATOR.

tive, and the other carries the condensed water back to the locomotive again, and so we call our system the return system; that is, we return the condensed water to the locomotive instead of pouring it on the ground. In order to get this water back there is a pump on the locomotive, and under certain conditions the suction may be strong enough so that instead of having a pressure in the heating pipes, we may have a vacuum.

Returning now to the air which we left in the conduit or space underneath the floor, it will be observed that there are a number of apertures *e e* through the floor, directly under the heater pipes. Through these apertures the air passes into the trunk containing the heater pipes, is warmed by contact with these pipes, and then passes out of the apertures *f f* in the trunk into the car. These apertures in the trunk extend the whole length of the car, both between and beneath the seats. From the main body of the car, the air passes out of the ventilators *g g* situated on the top of the upper deck.

The first experiment that we made after the car was fitted up with this device consisted in observing which way the currents would flow when the car is standing still. Quite to our gratification we found them moving in the right direction, namely, when heat is in the car, air passes into the hood *a* down through the pipe *b* into the space or conduit below the floor, thence up through the floor, over the heating system, and out into the body of the car, and, finally, out through the ventilators. It is clear I think why this should be so, since the exit of the ventilators is some 2 feet higher than the topmost point of hood *a*.

So one of the difficulties that was characteristic of the old Spear stove system has been apparently overcome very satisfactorily by this new scheme.

At first the apertures *e e* through the floor underneath the heater system were about 4 inches long and about ¾ inch wide and there was one opposite each seat. Also we had at that time only six ventilators in the upper deck. With a coach fitted in this way we made experiments as follows: We would load the car to its full capacity with men from the shops, the reason for that being that we could take a foreman along and

control the men in a way to secure the conditions we sought, and know at all times that we had those conditions. We made a trip to Johnstown, some 35 miles from Altoona, and back again. When we got pretty well over towards Johnstown, allowing neither doors nor windows to be opened during the trip, we took some samples of air in rubber bags, with a little hand bellows, walking the whole length of the aisle back and forth, until the bags were filled, several gallons of the air being taken in each case. Then we stood still on the track for about half an hour, without opening doors or windows, to see how well we ventilated when standing still, and took another sample. Then we put the locomotive on the other end of the car, and when we got nearly back to Altoona took a third sample. Those samples were analyzed several hours after the return from the trip, and we found that we were getting on the first trip about 500 cubic feet of air per person per hour, instead of 1,500, as we desired. Standing still we got about 340 cubic feet per person per hour.

We then made some modifications, increasing the size of the apertures underneath the heating system, and made another trip in exactly the same way; and in that case we got about 600 cubic feet of air per person when we were running and about the same when we were standing still, as in the previous trip.

It became evident from these experiments that we were not getting anything like enough air through the car; and we began then a systematic study to find what part of the passageways limited the flow. We first increased the number of apertures in the floor and enlarged their size until we finally reached this point; namely, we put an aperture 4 inches long and 1¼ inches wide every other 4 inches for the whole length of the car under the heater system; in other words, we had 4 inches of aperture, 1¼ inches wide, then 4 inches of floor, then 4 inches of aperture, and so on, on both sides of the car.

Also we increased the intakes *b* from 8 inches square to 14 inches square, and instead of having one on one corner, and one on the diagonally opposite corner, we put one on each corner. Then instead of having six ventilators in the top of

the car, we put on twenty. I have given you the final result of a number of successive trips, modifications being made from time to time. With these appliances what did we obtain? With these appliances it is easy to get 90,000 cubic feet of air per hour through the car. But unfortunately here is where we struck a snag, namely, we could only warm that air about 40° above the outside air. When the temperature is zero, it is perfectly clear that the car was uninhabitable for passengers. That was a serious difficulty, as you will all agree.

In order to overcome this difficulty, we planned one further modification, but further study showed that this modification was impracticable.

It is evident, since the trunk or box containing the heater pipes is small, since the passage of the air through this trunk is very rapid, owing to the large volume per hour, and especially since the cold air impinges against the heater pipes, only about half their length, owing to half the space only being apertures, that it is a reasonable query whether we are utilizing our heating system to the best advantage. Does the air that comes in through these apertures utilize that portion of the heater system between the two apertures? My hearers may say, why didn't you make your aperture continuous, from one end of the car to the other? This is what we planned to do, but on a little study, we found that it would be hazardous to cut the whole length of the floor system completely through. The floor system is necessary to the strength of the car. It holds the outside sill to the first intermediate, and is really a very important element in the strength of the car, and to cut through the floor the whole length, would so greatly weaken it, that we did not venture to try it. So we had to stop at this point; namely, we can take 90,000 cubic feet of air per hour into the car and out again, but we cannot warm it with our present heater system and our present means of utilizing it, and that is exactly where we stand to-day. Of course, the problem is not abandoned; we have not given up the question; we are now studying whether a continuous slot through the whole length of the car would warm that amount of air. Those experiments are being made off a car, so that we can

control the conditions. But I may be allowed to repeat, we have reached the point where we can get half as much air as theory calls for into a car and out again; but we cannot warm it.

I will only take a few moments more of your time. I want to give you one or two points that are rather interesting to me; and that seem to throw a little side light on the problem. During our experiments we had five or six thermometers hanging from the baggage racks for getting the temperature at different points in the car; and we had anemometers to measure the air currents, and we had a gauge on the heater system, so that we could tell what was going on inside the heater system.

During one of the trips we struck a very peculiar state of affairs; namely, the rear end of the car was 10° to 20° colder than the front end. This was a good deal of a puzzle for a little time; and, really, it was a thing we could hardly account for; but after a little study we found this very interesting state of affairs: As I told you, we had some twenty ventilators on the car. These ventilators are so made that when a current of air is moving at right angles to the axis of the ventilator, air is drawn out of the space with which the ventilator is connected. We found that with twenty ventilators on the car the suction was a little stronger than the supply. The front ventilators, acting first, made such a vacuum in the car that the regular intakes could not fill it and a current of cold air actually came down through some of the rear ventilators into the car. On closing some of the ventilators the difficulty disappeared. I think this has a bearing on the problem of ventilation, in this way: namely, that you must make your intakes to supply fresh air equal to your exits, or you will have the same difficulty. Some persons have thought that all that was necessary to do was to put ventilators on a car and let the air come in wherever it could. That was tried on some cars, and it was found in the winter season that the ventilators must be closed.

I said some time earlier in the evening that one of our problems was to exclude smoke and cinders and dust. That part of the problem we have as yet hardly touched. I don't

know to-day of any practicable means by which that can be done. I will say for your information that you will notice in Plate II, under the downtake a little reservoir *h*. We found, to our gratification, that cinders that were large enough to be so caught, come down into this reservoir and remain there. On the other hand, dust and smoke and very fine cinders pass along and up through the apertures and into the car. Indeed, when we had the twenty Globe ventilators and the maximum number appliances that I have described all open on going through the tunnel, the air of the car was so filled with smoke as to be quite suffocating.

In any system of ventilation it is absolutely essential that we should have control over it. Our scheme has been to have a valve in the downtakes; and possibly also valves connected with the ventilators, so that we could close them while passing through a tunnel, or when the wind happened to be in a direction to require it.

To our minds the problem of car ventilation stands now something like this. It is possible to get much more air into a car than any system now in use takes in. It is possible, if we could content ourselves with 20,000 to 30,000 or 40,000 cubic feet of air in severe weather to have such a ventilation system put on the cars to-day. Then in the milder weather we could increase it to the full capacity of the system. That phase of the question is being studied already quite earnestly. On the other hand, as everyone knows who knows anything about railroad matters, where there are 2,500 passenger cars requiring to be changed, it is simply ordinary business prudence to exhaust a subject pretty thoroughly and be sure of the ground before going ahead.

I am sure I am speaking the truth when I say that railroad officers appreciate the hardship of having to sit a number of hours in a badly ventilated coach as much as the public do. I can state, from my own knowledge, that they are thoroughly interested in this subject; and I am safe in saying that the intention is to prosecute it to a successful conclusion as soon as possible.

I thank you very much for your kind attention.

THE FRANKLIN INSTITUTE.

Stated Meeting, June 16, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

THE SMOKE NUISANCE AND ITS REGULATION, WITH SPECIAL REFERENCE TO THE CONDITION PREVAILING IN PHILADELPHIA.

(Concluded from Vol. CXLIII, p. 424).

DISCUSSION.

MR. W. F. DURFEE, C.E. [Correspondence]:—The smoke nuisance is far from being a modern annoyance. About six hundred years ago, when the population of London did not exceed 50,000, its citizens petitioned King Edward I to prohibit the use of "sea coal," and he responded by making its consumption a capital offence. His successors, however, were more merciful to the users of coal, and its employment was resumed; but again, in the reign of Elizabeth, there were loud complaints against it, and, in 1661, John Evelyn, in his *Fumifugium*, laments that, "owing to the increase of coal smoke, the gardens no longer are fruitful." In the centuries that have followed there have been a number of parliamentary inquiries and some legislation intended to mitigate, if not remove, the evil, but, nevertheless, the consumption of bituminous coal has rapidly increased in London, and the inquiries and legislation relative to it have all ended—in smoke.

The nuisance of smoke in London is, as it has been for several hundred years, felt most severely during the prevalence of fog, and the vital statistics of that metropolis furnish abundant proof of the great evil of a smoke-contaminated atmosphere. We are told that "during the fogs of 1879-80, asthma increased 220 per cent. and bronchitis 331 per cent.;" and that "in the week ending February 13, 1882, the death rate, owing to the dense fogs, rose from 27·1 in the previous week to 35·3; diseases of the respiratory organs rising to 994,

the corrected weekly average of this class of diseases being 430."

In discussing the smoke nuisance, which is so unpleasantly asserting itself as the manufacturing and commerce of the chief cities of our land augment, it is well in the outset to have a clear understanding of the objectionable elements of that exceedingly unpleasant and unsanitary fumid substance, which in English speech is called "smoke."

Smoke is the result of an imperfect combustion of carbonaceous substances, and always has, as an offensive, distinguishing component, more or less of solid carbon in a finely divided or flocculent condition (commonly called "soot"), associated with which are various gases and vapors, the character and volume of which depend upon the composition of the combustible employed and the degree of perfection attained in its burning.

In some coals we have present a notable amount of sulphur and hydrogen associated with their carbon; and the gaseous products of the imperfect combustion of such fuels would contain carbonic acid, carbonic oxide, sulphurous acid, sulphuric acid, the vapor of water, ammonia, nitrogen, carbureted hydrogen, and a modicum of other vapors and gases of less importance. All of these gases and vapors escape from the chamber in which the fuel is imperfectly burned, at a high temperature, up-bearing and spreading abroad the flocculent solid carbon or soot.

Most bituminous coals, when imperfectly burned, produce smoke of substantially the above composition, the elements of which are as variable as the conditions of temperature, and the "personal equation" of an unskilful fireman can make them. It is entirely unnecessary to prove that such smoke is injurious to health, or that it is destructive to vegetation, as these points are admitted by every candid investigator. What is demanded is a remedy for the existing evil. Fortunately that remedy is not doubtful, or difficult of acquisition. It consists simply in effecting the perfect combustion of the fuel used, and in the use of a fuel whose perfect combustion will not produce deleterious gases.

It will doubtless be asked: "Why, if the remedy is so simple, has it not been applied long ago? Why has London smoked and suffered for six hundred years, when a cure was at hand?" To answer this question is as difficult as to say why all men are not honest, when it is universally admitted that "honesty is the best policy." London is smoky because it fails to prevent the formation of smoke; and Paris is smokeless because it insists on a perfect combustion of its fuel. The remedy for the smoke nuisance is in the hands of the people who complain of its annoyance, and they have only to imitate the conditions existing in Paris, or any clean, smokeless city, to be rid of it forever.

It will doubtless be asked—what means have been successfully used in the past for the prevention of smoke? Answering this question in a general way, it may be said that all expedients for the prevention of smoke that have been effective have involved a regulated uniform supply of fuel in proportion to the requirements, and a regulated adequate supply of air to ensure its perfect combustion.

It would require much more time than is allotted to me to describe the various forms of apparatus that have been devised for carrying out practically the general principles of smoke prevention; but a brief reference to a few of the more prominent of these may not be without interest.

The first successful apparatus, of which we have any knowledge, that burned fuel without the production of smoke, was invented by Abu Musa Dschabir Ben Haiyan (better known by the name of Geber), an Arabian alchemist, who lived about the end of the eighth century. He is credited with the discovery of nitric and sulphuric acids, and of certain preparations of mercurial and other metallic salts. Geber called his furnace the Tower of Athanor, and from its construction a steady and uniform heat could be maintained for an indefinite period. Its principal feature was a high cylindrical tower for containing the fuel. This tower was flanked by two combustion chambers, in or over which the substance or vessel to be heated was placed. These chambers were connected with the central tower near its base, by flues, in which were dampers for regulating the flow of the gas generated from the fuel. This fur-

nace of Geber was in fact a "gas furnace," and the general principles involved in its construction were the same as we see in every-day use in all self-feeding, base-burning stoves, and in many gas furnaces for metallurgical purposes; in fact, many of the so-called improved gas producers are no better and but slightly different from that invented by Geber over one thousand years ago, and he must be regarded as the discoverer of the great advantages resulting from converting solid fuel into a combustible gas, and then burning that gas in a combustion chamber separate from that containing the solid fuel. Geber's furnace was not a mere suggestion, but was in common use by chemists in all well-appointed laboratories, until the beginning of the present century.

In 1785 James Watt invented a method of smoke prevention, which is very simple, and in the hands of a careful fireman is very effective. I speak from personal knowledge, as I carried it out successfully in the burning of bituminous coal under a steam boiler thirty-eight years ago.

Various methods suggested have been patented, and some of them carried into successful practice, for preventing smoke by feeding the raw coal into the furnace beneath that already in a state of ignition. Other inventions contemplate the automatic supply of the solid fuel in a regulated constant manner; but from the time of Geber to the beginning of the present century no person suggested the employment of the ideas embraced in his invention, on a large scale in manufacturing operations, and the modern use of the waste gases from blast furnaces and refinery fires (which may be fairly regarded as gas producers) is believed to have originated with M. Aubertot, superintendent of the forges of Vierzon, in the Department of Cher, who obtained a French patent for it in 1807. His first apparatus was designed for the burning of lime or bricks and the cementation of steel.

The employment of the waste gases of blast furnaces was described by M. Berthier in 1814, but gas was not much used as a fuel until 1832.

The application of gas as a fuel for steam boilers was first made in 1832 or 1833, at a furnace in the Department of the

Mense, but it was not successfully employed until 1835, when MM. Dufournes, Thomas and Lourens solved this interesting problem in a satisfactory manner. In 1836, furnaces having boilers fired by gas were working with success at Neiderbrunn. In 1837 Wilhelm von Faber du Faur made successful experiments at Wasseralfingen, in Würtemberg, to burn the gases of blast furnaces in a reverberatory furnace, for the purpose of refining pig iron.

In 1839, M. Bunsen, of Cassel, devised an apparatus for collecting the waste gases of blast furnaces, for use under boilers. In 1840, Mr. Philip Taylor, of Marseilles, applied at a blast furnace at Rustel, in the Department of Vaucluse, the following-described construction: Gas was carried in a large cast-iron pipe from the upper part of the furnace to the boilers, which were placed at some distance from the furnace and was passed under the boilers through a number of slits, between which were other slits (regulated by a valve) for the admission of air. This is believed to be the first recorded instance of the employment of an arrangement which is now, with slight modification, in general use.

In 1845 Mr. James Palmer Budd obtained an English patent for the application of the heat, flames and gases of the blast furnace to the heating of hot-blast stoves, which was carried into practical operation at Ystalyfera Furnace, which was using anthracite coal. Mr. Budd calculated the annual saving in money, by this use of the gas, at £350; and so satisfied was he with his success in utilizing the waste gas, that (says Dr. Percy) he even ventured to draw the following conclusions: "It would seem to be more profitable to employ a blast furnace, if as a gas generator only, even if you smelted nothing in it, and carried off its heated vapors by flues to your boilers and stoves, than to employ a separate fire to each boiler and each stove. These considerations irresistibly suggest to me a great revolution in metallurgical practice—a new arrangement, in fact, of furnaces and works, by which considerably above £1,000,000 a year might be saved in the iron trade alone." This prediction of Mr. James Palmer Budd has been in no small measure realized by the invention of Mr. Frederic Siemens,

who, in 1856, patented his well-known regenerative gas furnaces.

These furnaces have now been in use in this country over thirty years, and their excellent qualities are well known to all metallurgical engineers. These furnaces can consume, without the production of smoke, any solid substance that is used as a fuel, and many things that it would be impossible to use in other furnaces. Gas from Siemens' "producers" can be used under boilers with entire success, and the writer used such gas for boiler fires twenty-eight years ago.

In 1868, the writer hereof erected the first steel works in which gas was exclusively used as a fuel; in these works were two puddling furnaces, three heating furnaces, one 24-pot melting furnace, and ten gas producers. Gas from the producers was used to fire the boilers. The fuel employed was ¾ very fat bituminous coal, and ¼ anthracite coal dust. The waste products of combustion passed into the atmosphere through a chimney 100 feet high, having a flue 6 feet in diameter. There was no smoke discharged from this chimney, and although the works were in the immediate vicinity of residences and cultivated grounds, there was no complaint of smoke or noxious vapors of any kind.

Every one is familiar with the easy way of preventing a gas flame from smoking, and I am only speaking from my own practical experience, when I say that it is relatively just as easy to prevent fuel from emitting smoke.

The community that is a sufferer from the smoke nuisance, whenever it really resolves to put an end thereto, will find no difficulty in securing the services of engineers competent to devise and construct the proper apparatus for attaining that result.—West New Brighton, Staten Island, N.Y., April 20, 1897.

Mr. Arthur Kitson:—Whilst agreeing with most of the remarks made by the eminent gentlemen who have preceded me this evening, I must say that, in my judgment, the most injurious phase of the smoke nuisance has not yet been dealt with. It is the popular idea that the really detrimental and dangerous part of smoke, when inhaled, is the *visible* portion—

the particles of carbon that blacken the atmosphere—and it is believed that the cure for the nuisance is to render this carbon *invisible*, by burning it to carbonic acid gas. And the remedies that have been offered for its abatement to-night are confined to this popular notion.

Down-draft furnaces and mechanical stokers, invaluable as they may be, and undoubtedly are for many purposes, cannot rid us of the ammonia and sulphurous acid gases that constitute the worst feature of the evil we are here to discuss.

The statement, quoted by Mr. Outerbridge, that smoke is not really injurious to life—but, on the contrary, is healthful—created some amusement. What the writer evidently meant was that the inhaling of the *visible* constituents of smoke was not injurious; and this is attested by Dr. Littlejohn, of England, who recently reported on this subject to the Sheffield Board of Health. He says: "That black smoke in itself, as a thing breathed, is prejudicial to health, is even doubtful. Miners, who live in an atmosphere of carbon dust, are the next healthy class to farm laborers in the kingdom. When they die, their lung tissues are found of an inky blackness, but Hirt, a great authority on vital statistics, thinks it in the highest degree probable that coal dust (carbon) possesses the property of hindering the development of tuberculosis (consumption), and of arresting its progress."

Now, it is a well-known fact that the death rate in the smoky city of London is greatly increased during the months when fog is prevalent. In a fortnight of heavy smoke-fog, which prevailed in 1886, it is said that the rate of mortality rose from 16·6 to 40 per thousand. One authority asserts that an ordinary London smoke-fog kills from 170 to 200 persons per day in that metropolis.

What constitutes the fatal portion of the smoke-fog one may readily discover. In Paris, where fogs are frequent at certain periods of the year, the death rate is not so materially increased, and in Paris coke is the fuel generally in use. We have evidence sufficient to show that the visible part of smoke is not particularly fatal. The inference is sufficiently strong to warrant acceptance that the really dangerous ele-

ments of smoke are those invisible gases formed whenever soft coal is burned in an ordinary furnace or grate. Soft coal consists of carbon, hydrogen, sulphur, nitrogen and sometimes chlorine, with silica, iron, etc., forming the ash.

The burning of coal is really a chemical problem, and consists in the oxidation of the first three elements. If the supply of oxygen is ample, its distribution perfect, and the temperature of the elements sufficiently high, the products of combustion will be carbonic acid gas, steam and sulphurous and sulphuric acids. Part of the free nitrogen combines with the hydrogen and passes off as ammonia.

Unfortunately, however, the ordinary methods of burning coal will permit neither an ample supply of oxygen nor its proper distribution, and, in most cases, that portion of the coal requiring a high temperature is cool during its most critical condition. The result is, that instead of getting, as we should otherwise do, *invisible* products of combustion, we see clouds of black smoke—unconsumed carbon—emanating from our chimney stacks, blackening and disfiguring our buildings, hiding the sun's rays, and hanging like a pall over our cities. This is the really injurious feature of the visible portion of smoke. Whilst I believe carbon is the least harmful of the various ingredients which go to form smoke when inhaled, its physical effects in obliterating the sun's blue rays—which are essential to healthy vitality—are sufficient to warrant us in declaring war against the nuisance. Light is as essential to the well-being of animals as it is essential to plant life.

To some it may appear that I am giving undue prominence to the effects of the sulphur and nitrogenous and chlorine compounds, considering how small is the proportion of these to the principal matter constituting coal. It may, therefore, surprise those gentlemen to learn what amount is actually given off in localities where careful statistics are kept. "If the sulphurous acid alone which escapes into the air of Sheffield were deposited by rain within the area which gives it off," says a well-informed writer, "the ground would be washed every year with 1,000 tons of it per square mile." Another statistician informs us that the amount of ammonia annually sent off by the chim-

neys of London would, if properly treated, furnish over 700,000 tons of sulphate of ammonia. And here we have an illustration of a truth too often forgotten—that the law of healthfulness is the law of economy. The value of these waste products alone should be a sufficient inducement for us to seek some better system of combustion than that now prevailing. The value of this vast quantity of nitrogenous matter disfiguring and vitiating London's atmosphere exceeds that of all the fertilizers which England imports annually from Chili and Peru.

From what I have said, you may infer that I cannot regard the mechanical devices known as smoke consumers, mechanical stokers, down-draft furnaces, as offering the final solution of this problem. To reduce all of the carbon to carbonic acid before allowing it to reach the atmosphere, is indeed desirable, and one step—perhaps a long step—in the right direction. But these contrivances do not get rid of those other objectionable products.

The only proper solution I know of is the conversion of coal into gas, and its purification before distribution. Fuel gas, as it is called, meets every objection that can be raised against the burning of coal. It is scientifically correct. It is the only means for ensuring perfect combustion and avoiding the evils I have enumerated.

Remembering that combustion requires an intimate contact between the molecules of the combustible and the oxygen of the air, and that the more intimate the mixture and closer the contact the more nearly perfect the combustion, we can readily see how unscientific is the ordinary method of burning coal. The ordinary soft-coal furnace is a distilling apparatus, where soft coal is thrown upon a red-hot bed of fuel, and the valuable hydrocarbons and volatiles are distilled off and conducted unconsumed by a chimney to vitiate the atmosphere. Compared with this, the down-draft furnace, in which this volatile matter is made to pass through the fire and consumed, is entirely correct.

Before leaving this subject, it may be of interest to some members of the Institute to learn that a century and a quarter

ago Benjamin Franklin was the greatest living authority on smoke prevention. He devised two or three different forms of smokeless grates, one of which he used during a three years' residence in London. The principle was the down-draft, and I believe he anticipated the celebrated James Watt in the invention of this form of furnace. The burning of lump coal is a gradual process; indeed, it may be truly said that coal cannot really be burned in lump. Its exterior surfaces begin to break into molecules; in fact, this molecular condition is essential for combustion. The inner portions of the coal, however, remain intact, and combustion cannot occur until all the exterior portions are burned away. In burning, however, the incombustible portions of the coal (silica, alumina, etc.,) remain as a deposit of ash, and serve to check the moleculization of the carbon underneath. For this reason a fire will often "go out" long before the carbon is consumed, the ash forming a sort of "insulator" to the contact of the air.

The smaller the coal the better the combustion, providing the air is brought properly in contact with it. Hence coal-dust burners have been used with great advantage as heating agents in securing better combustion. It is as gases, however, that molecular contact and intimate mixtures are obtained in practical perfection, and as this is the chemical theory of combustion, it follows that the conversion of coal to gas is the most reasonable method to adopt.

The gasification of coal is no longer an expensive process. It can be performed with a loss of not over 14 per cent. of the theoretical heat value of the coal, a loss which is considerably more than offset by the more nearly perfect combustion and greater efficiency of the gas. In other words, for almost all industrial purposes it would pay handsomely to convert the coal into gas, and use the gas for heat and power purposes rather than burn the coal directly. I have to-day a gas plant operating with hard culm from the Scranton culm piles, and am running a gas engine with this gas at the rate of 1¼ pounds of culm per horse-power. Culm is, as you know, a waste product of the coal mines, because of the difficulty of burning it. Yet, when converted into gas, it is more efficient

for industrial purposes than are the better grades of coal if burned in solid form.

Let me say, in concluding, that I am not a believer in legislative methods of reform. The way to stop the smoke nuisance is to educate our manufacturers to understand that they are not only injuring the city and endangering the lives and happiness of thousands by their methods, but that they are also wasting thousands of dollars. Should the first plea fail to strike a responsive chord in their minds, the latter will be more likely to do so.

MR. WILLIAM M. BARR:—In metallurgical operations, the construction of a furnace for burning any kind of fuel is usually in charge of one who understands the principles of economic and smokeless combustion; it is to be expected, therefore, in the interests of trade, that such furnaces shall be efficient and economical, also that they shall, in the interests of good citizenship, be as nearly as possible smokeless in operation.

The problem which seriously confronts us in Philadelphia, by reason of its numerous, varied and non-centralized industries, is the possibility that steam boiler furnaces may, under the changing conditions of fuel supply, become public nuisances.

Most of the boiler settings in Philadelphia, especially those erected more than four or five years ago, have grates averaging not more than 24 inches below the under side of the boiler shell, and for anthracite coal this distance has been found to yield good results.

If these steam boilers are to continue in the use of anthracite coal no change need be made. In the case of bituminous coal, however, the problem is altogether different, because the combustion consists of two distinct processes.

When a furnace door is opened to receive a fresh charge of fuel, that act in itself lowers the temperature of the furnace by the admission of cold air over the fire, the fuel is cold and distributed over the whole surface of the grate, a distillation of the hydrocarbon gases immediately occurs in such pieces as are in contact with the incandescent fuel underneath, and this occasions a further lowering of temperature. Now, if the

first product of this combustion be carbonic acid gas, which is probably true, it is certain that it is almost immediately changed into carbonic oxide gas during its passage through the burning fuel. The distillation of the volatile matter from the coal has, as just stated, the effect to lower the temperature of the furnace, and this favors the accumulation of minute sooty particles of carbon, which, being carried off by the other products of combustion, give color to the escaping gases at the top of the chimney. In the course of a few minutes the temperature is regained in the furnace; at the same time a less distillation of hydrocarbon gases occurs; as a result, better conditions of combustion are had, and in consequence less carbonic oxide gas and fewer particles of soot; in other words, less visible smoke.

The second stage is that of the combustion of the fixed carbon or the coke of the coal; this process is without smoke, the products being wholly transparent.

Hand-firing for small steam plants is likely to continue, and it is important, therefore, that the furnace be so constructed that if ordinary care be exercised the quantity of smoke emitted in any neighborhood may be less than that constituting a nuisance.

Bituminous coal should be broken in small pieces, the smaller the better, thinly and evenly spread over the fire; thick firing, especially if large lumps are thrown into the furnace, is not conducive either to economy or to smoke prevention.

Referring again to the distance of the grate bars from the boiler, my own judgment is that, for bituminous coal, the grate bars should not in any case be nearer than 40 inches to the boiler, if the coal is one likely to give off smoke. Some bituminous coals do not give off as much smoke as others, and steam boiler furnaces designed for localities where a comparatively smokeless coal will be continuously used, may have the grates 36 inches below the under side of the boiler. Some experiments have been made with grates 48 inches distant from the boiler where unusually smoky coals were used, and with excellent results. The explanation of this is easily had, and is probably nothing more nor less than the fact that bituminous

coals require a roomy furnace for their perfect combustion, it being a common experience that roomy combustion chambers which favor the better admixture of air with the hydrocarbon gases and vapors distilled from the fire, give off less smoke than others.

To meet the local conditions of this city, my recommendation would be that, in all cases where a change is to be made within the city limits, in order that bituminous coals may be burned instead of anthracite, the boilers be reset, so that the space between the grate bars and the under side of the boiler should approximate 40 inches. The cost would not be great, and, with careful firing, would almost effectually prevent smoke.

For large steam plants automatic stokers may be used to good advantage, as automatic and continuous feeding is favorable to economy, as compared with ordinary hand-firing, while it also lessens the escape of smoke, because of a more thorough combustion. It matters little whether they operate upon a dead plate caking the coal, and afterwards burning the coke from which the gases have been distilled, or whether the coal be fed from underneath; either form, if properly cared for, will do good service.

The down-draft furnace has been very successful in smoke prevention, so also has the fore-and-aft system of firing, in which the products of combustion of one furnace, with its unconsumed gases and sooty particles, are made to pass over an incandescent body of fuel in another furnace, by alternately firing one grate and then the other. Changing the current of gases through the furnace to the chimney by means of dampers, however, involves a little extra labor on the part of the fireman.

Altogether, the solution of the problem is neither difficult nor impossible; it simply requires that the conditions be fully understood, and that the furnace be adapted to the required conditions, based upon a knowledge of the constituents of the fuel to be burnt. The subject is not a new one, and reliable experimental data are easily procurable for the guidance of all parties concerned, and the proper remedy can in each case be

applied without working hardship to the owner of a steam plant, while relieving a neighborhood of what in time may become an intolerable nuisance.

Dr. Wm. H. Ford, President Board of Health, Philadelphia, Pa.:—I desire to say that the Board of Health feels very much gratified that the Franklin Institute has taken hold of the question of the smoke nuisance. This venerable Institute is particularly qualified for dealing with practical and scientific problems with which the municipality has oftentimes to grapple, and its suggestions received from time to time will enable the municipal government to deal more intelligently with questions involving the health and comfort of its citizens. On the other hand, it is interested in advancing industrial arts and in one hand, it is interested in advancing industrial arts and in legislation, and, on the other hand, it is interested in solving problems affecting the health of the community, the solution of which is based more or less upon a knowledge of scientific principles. Thus the Institute, in furnishing information on questions of great public interest, can be relied upon in giving judicious advice without prejudice to any interests involved.

The discussion this evening has been of a thoroughly practical character, and has developed points of great interest which must have a practical bearing upon the solution of this vexed question. Whether such a nuisance exists, or whether the production of smoke in large volumes by manufacturing establishments, locomotive stacks and the like, is a nuisance, hardly enters into the discussion, because the fact is self-evident and beyond dispute. Various cities, particularly those located in our Western country, where bituminous coal is almost the sole fuel used, have from time to time legislated on this subject, and some of the laws which have been passed are exceedingly stringent, perhaps more so than the circumstances demand. In our own city, until within recent years, there has been little annoyance from the production of smoke, for the reason that anthracite coal was almost entirely the fuel used in our factories and exclusively so in the household. But the development of the bituminous mines in the State has brought to our doors, at cheap prices, large quantities of soft coal,

which is gradually supplanting the anthracite coal. The statements made here to-night show that the ratio of increase of consumption of bituminous coal is very much greater than that of anthracite coal, and this ratio, for various practical reasons, is destined to increase. The result is, that in certain localities in the city the smoke nuisance already exists to an extent that calls for some legislative regulation preventing the discharge of smoke, or, at least, restricting the practice.

There is, at the present time, before the Legislature a bill giving authority to cities in this Commonwealth to pass ordinances prohibiting the discharge of black, brown or gray smoke into the atmosphere. This proposed legislation originated on account of a doubt that has arisen as to the authority of City Councils to legislate upon this subject. The injury that smoke causes is seen in the household by its damaging effect upon fabrics, furnishings, in the begriming of the exteriors of buildings, and also in the discomfort which it causes when this smoke is produced in large quantities and in considerable density. There is no question as to the existence of a nuisance such as is described as "a nuisance at common law." The question whether the discharge of smoke into the atmosphere is injurious to the public health has been disputed by some, but from the evidence collected there can hardly be a reasonable doubt that there is from this cause a possibility of injury to health. The carbonic oxide and carbonic acid that are discharged into the atmosphere no doubt become speedily diluted, and it is not likely that they have any serious influence upon health; but the finely divided carbon and the sulphurous acid and tarry matters resulting from the imperfect combustion of soft coal, are undoubtedly agents active in their effect upon health.

It has been stated here this evening that the sulphurous acid, and perhaps the fine carbon particles, might be beneficial as an aërial disinfectant, but there certainly does not appear to be any evidence that the smoky air of towns is freer from the poisons of specific diseases than the air of other places. It seems to be a justifiable inference to assert that the finely divided carbon which constitutes smoke must have a mechani-

cal influence upon the mucous passages, particularly of the lungs, and it may be that the sulphurous acid in the air may also prove irritating. It is said that persons visiting London, who are suffering from weak lungs, complain of the irritating effect of the air. Whether it can produce attacks of bronchitis and the like is not certainly determined, but it will scarcely be disputed that persons suffering from pulmonary disorders have their convalescence delayed thereby.

The question that mainly concerns us this evening is the possibility, or rather the practicability, of devising simple means of preventing the smoke nuisance, and such means as may be applied conveniently and without great expense. It appears from what has been said by the experts from different cities who have taken part in the discussion this evening, men who have practical knowledge of this subject in all its branches, that it is entirely feasible to introduce appliances by which the smoke can be consumed, thus preventing a nuisance and at the same time being somewhat advantageous to the establishments by economy in the use of coal. The mechanical stoker seems to have the preference, and as this apparatus has been used very largely in England with manifest advantage, and has been applied in many instances in our own country, and here in our own city in large establishments with great success, it is very evident that legislation prohibiting the production of colored smoke would not prove a hardship, and it is indisputable that such prohibition is required in the interests of the comfort of the citizens, if not for the protection of the public health. It has also been developed by this discussion that in many instances all that is necessary is careful, common-sense firing. This necessitates the careful selection of a fireman, his proper compensation, and the proper supervision of his work in order to require orders to be carried out with precision.

It may be said that Philadelphia, at the present time, is not a very smoky city, and why not wait until the nuisance exists before taking steps to correct the evil? To the judicious mind this does not seem to be the proper course of action. It is much wiser to prevent than to correct, and a regulation prohibiting the emission of colored smoke at the present time will

not only correct the evil as it exists to-day, but will prevent the increase of an evil which is destined in time to cause very serious annoyance and loss of money by the deterioration of property, and possibly, in certain localities, by the injury of the public health. By all means, then, let the wiser course be pursued, which is, to take time by the forelock, and to prevent in the early stage what may hereafter become a nuisance assuming such proportions as to make it exceedingly difficult successfully to grapple with. The Board of Health places great confidence in the ability, wisdom and practical knowledge of the Franklin Institute, and for that reason has solicited its co-operation in securing the application of such measures as will compass this subject thoroughly, and overcome, without unnecessarily injuring the industrial establishments of the city, an evil which is already beginning to attract the attention of the people, who are anxious that measures be enforced for their protection.

MR. H. H. SUPLEE:—One of the principal causes of the production of smoke is the chilling of the fire and interruption to combustion due to the proximity of the comparatively cool boiler to the incandescent bed of fuel. The temperature of the fire is variously estimated at 2,500° to 2,800° F., while that of the boiler is usually below 350° F., and the result is a chilling of the gases and a precipitation of the carbon. This is well shown by holding a cold dish above a gas flame and observing the deposit of soot as soon as the flame is cooled.

This fact was well appreciated by James Watt, and his patent of 1785 contains as clear a description of the action and its remedy as has been made since. The furnaces shown in this patent and illustrated in Galloway's "History and Progress of the Steam Engine," London, 1830, show what is practically a gas-producer, a combustion chamber for perfecting the combustion before the gases reach the boiler, and what is practically the modern "down-draft" furnace. Watt says: "I cause the flame to pass through a very hot funnel, flue or oven, before it comes to the bottom of the boiler, by which means the smoke is more effectually consumed."

In recent times such furnaces have been constructed for

burning wet tan-bark, sawdust and other inferior grades of fuel, and if the furnace and combustion chamber are properly proportioned, little or no smoke is produced. For large plants, however, it is undoubtedly advisable to burn the fuel in a separate gas-producer and deliver fuel gas to the boiler furnace, thus enabling the lowest grades of culm to be used without smoke. Ultimately, I have no doubt that it will be found far more economical to use producer gas in gas engines.

The question of oil fuel seems to be opposed mainly because of the inadequate supply; and in connection with that, attention may be called to the valuable paper of Chief Engineer Nabor Soliani, of the Italian Navy, read at the Marine Congress, at Chicago, in 1893, in which he shows that with proper care a good smokeless fire can be maintained with oil and coal used in combination, about one-fourth of the fuel being oil refuse and the remainder coal.

DR. COLEMAN SELLERS [Correspondence]:—Finding it impossible for me to be present at the meeting on the 19th inst., at which the discussion in regard to the "Smoke Nuisance and its regulation with special reference to the condition prevailing in Philadelphia" is to be continued, I would say that, personally, I can add but little to what has been so ably presented by those who attended the meeting of April 21st, or contributed by correspondence to the discussion, but the subject engaged my attention actively between the years 1847 and 1857, when residing in the city of Cincinnati, where the constantly increasing consumption of bituminous coal both in private houses and in factories added year by year to the discomfort caused by soot.

Legislation is necessary, but whatever is done in the direction of ordinances should be based upon what actually can be accomplished without serious loss or expense to those using smoke-producing fuel.

Residing in a part of Philadelphia where there are no factories burning bituminous coal, the smoke nuisance has proceeded mainly from the locomotives in the yards of the near-by railroads. That the nuisance can be abated in locomotives by judicious firing, needs no further proof than that afforded by

the correspondence of Mr. Edward Longstreth and Mr. Samuel M. Vauclain. Both of them show what part the fireman himself plays in the management of the fires so as to make the combustion as nearly perfect as possible with the least smoke.

I would suggest that inquiry be made into the condition that obtains in regard to the starting of a fire with bituminous coal in the yards of the railroad companies, as the number of engines that must be prepared and made ready for the trains necessitates the frequent re-starting of fires; hence if care be not exercised at these points the residents of the city in the neighborhood must necessarily be more or less incommoded.

I have noticed in the city of London that the starting of fires in the afternoon at the great electric light stations has been accompanied with such enormous volumes of black smoke as to give to the neighborhood the appearance of an immense conflagration, and this at the time of the year when London is most free from smoke. At the time that I noticed this effect, mechanical stokers were not employed, and the great discharge of smoke, though coming from very high chimneys, was confined chiefly to the period of starting the fires and was less apparent afterwards.

The information that has already been laid before the Institute by those who have contributed to this discussion seems to me sufficient to show that it is possible to burn smoke-producing fuels to much better advantage than is done in common practice, hence the need of an ordinance that can be enforced, by an earnest effort on the part of law-abiding citizens in the spirit of justice. The information laid before the Institute should be gone over carefully by the committee which the Institute has appointed for the purpose, and the ordinances that have been passed in various cities for the abatement of the smoke nuisance should also be considered in reference to the action that should ultimately be recommended to the Mayor and the Councils of the city of Philadelphia, as practicable and likely to be beneficial.

Electric light and power stations depending upon coal can be operated without any excessive discharge of smoke into the

air, and probably without inflicting any hardship upon the companies engaged in this work. I think, however, that attention should be given to the gain that would accrue from the use of water-power that is within easy reach of Philadelphia, and the introduction of electricity created by the water-power, as supplementing what can be obtained from coal.

It has only been within a very few years that the judicious employment of water-power transmitted to users by electricity has been possible, and what has now been done in this and other countries shows the enormous importance of the utilization of what has been placed at our disposal by nature in the streams within reach. Legislation is needed to enable these water-powers to be so used. Such legislation has been sought, but has been met by the strong opposition of those who consider the fishing interests of paramount importance and liable to be wholly destroyed by power-development schemes. I think, however, that the danger has been very much exaggerated and too little attention paid to the real advantages that will accrue to the city of Philadelphia by the fostering of these power schemes with due attention to all other interests involved. Users of power are awakening to the knowledge that the mode of transmitting power by shafting and other mechanical contrivances is wasteful in the extreme, as compared to what can be accomplished by electricity. I think, therefore, that it would be well if some of the earnest thought of those interested in the abatement of the smoke nuisance were turned also in the direction above indicated.

Mr. Wm. A. Ingham [Correspondence]:—There is no smoke nuisance in Philadelphia. Our clear skies prove that.

London, Pittsburgh and Chicago have a smoke nuisance, and I think all this recent movement here is what I would express mathematically as an equation of the second degree. That is, the above-named cities have a real smoke nuisance, therefore Philadelphia has the right to have one. If not, she will be behind the age.

I have looked south and east and north and west from the Bullitt and Bourse Restaurants. I have counted the steam discharges (every one representing a steam engine run by coal)

and have also counted the chimneys emitting smoke. Within that horizon there is not one in fifty engines which emits black smoke. This does not include the Kensington iron mills nor the sugar refineries.

Smoke in moderate quantities is not a *nuisance*. Here I must discriminate: (*a*) A nuisance is whatever injures or annoys. (*b*) A nuisance is whatever is injurious to health, though it may not be perceptible to the senses.

(*a*) Excessive black smoke, as in London, Pittsburgh and Chicago, smuts and dirties linen and furniture.

Aside from smut and dirt, is smoke unwholesome? If not, there is no reason for the Board of Health to intervene.

(*b*) Now, I do not hesitate to say that a moderate amount of smoke in our atmosphere not only is not unhealthful, but acts as a purifier.

Smoke, besides unburnt carbon, which is hygienically inert, contains sulphur, which is a well-known disinfectant.

I *believe* the malaria in the Juniata Valley has materially diminished since the Pennsylvania Railroad Company has been saturating the atmosphere with smoke from its engines. But I cannot *prove* this, as I have no statistics.

If smoke is a nuisance anywhere, which is certainly not the case at present in Philadelphia, then it is perfectly easy to consume all smoke under stationary boilers, which constitute the great majority of coal users.

I say it is perfectly easy to do this. There are twenty (possibly fifty) efficient devices to consume smoke. The only question for the consumers is, will it pay?

While I admit that a person who burns his smoke, instead of wasting unconsumed carbon at the top of his chimney stack, will make some saving in fuel, I am not prepared to say that even with the best appliances available at present it will be economical for him to burn his smoke.

And this is probably the reason why these devices have not been universally adopted. They do save what was unconsumed carbon. But they cost so much to install and operate, that the balance of saving is on the other side.

To sum up:

(1) There is no *smoke nuisance* at present in Philadelphia, as is shown by our clear skies.

(2) The small amount of smoke emitted from our chimneys may, *perhaps*, be a benefit rather than an injury.

(3) It is perfectly practicable to consume smoke in stationary boilers.

As to locomotives, that is another story. It can be done, however, though at considerable cost and some loss of power. The best way, in my opinion, for locomotives, is to avoid *generating* smoke by using smokeless fuel, anthracite, coke or smokeless soft coal.

MR. WASHINGTON JONES [Correspondence]:—Any discussion of the alternatives of "smoke or no smoke," or, in other words, the perfect or imperfect combustion of bituminous fuels, in large quantities, to me seems like 'threshing old straw;" for the numerous, carefully-made experiments (and the published reports thereon) by competent chemists and engineers, are conclusive, and, if not known, should be known by all who are interested as steam users, too many of whom are so indifferent to the material saving that may be effected by firing properly, that they neglect to have instructions given to their firemen, when and how to replenish the fires.

I will venture, in this paper, to give a few extracts from authorities on the subject: In "The Economy of Fuel," by T. Symes Prideaux (Weale's Series, London, 1853), paragraph 10, will be found the following: "It is commonly but erroneously supposed, that when no smoke appears at the chimney top, combustion is perfect. Smoke, however, may be absent, and yet the carbon may have united with only 1 atom of oxygen, forming carbonic oxide (a colorless gas), instead of with 2 atoms, forming carbonic acid, and consequently have performed only half the duty, as fuel, of which it was capable, whilst the loss of duty on the coal taken as a whole (supposing all its hydrogen to have become oxidized), will be upwards of 40 per cent." Again, in the concluding words of paragraph 13: "A furnace, immediately after a fresh supply of fuel, requires more than double the quantity of air it did the instant before, whilst we have no contrivance for furnishing such a sup-

ply, although without it, throughout the space of time during which rapid gasification of the hydrogenous portion is going on, more than half the fuel consumed is wasted, and passes off unburnt, becoming thereby not only totally unproductive in itself, but absolutely an agent of evil, by robbing the furnace of the heat absorbed in its own volatilization."

In the *Journal* of the Franklin Institute, (third series, Vol. XXXV), will be found an article copied from the (London) *Mechanic's Magazine*, containing the report of a commission consisting of Messrs. Longridge, Armstrong and Richardson, appointed by the Steam Colliers' Association, of Newcastle-upon-Tyne, to determine the value of Northumberland coal compared with that mined in Wales, which submitted the following: "On the Use of Steam Coals, etc., in Marine Boilers." They say, in paragraph 1: "That the coal from your district, commonly called the 'Hartley's" may be consumed in ordinary multitubular marine boilers without making any smoke. (2) That this may be done without the adoption of any of the various schemes which have been brought before us. (3) That it does not involve any loss of power or economy; but that with a given boiler *more* water may be evaporated, whilst no smoke is made, than can be evaporated with the hardest firing on the usual system accompanied by a dense smoke; and further, that the economic effect, or the quantity of water evaporated by 1 pound of coal, is greater when no smoke is being made, to the extent of from 17 to 22 per cent."

It is to be regretted that the report does not define the phrase "usual system;" but, it may be assumed to mean—thick fires and closed furnace doors—as the final report (see (London) *Mechanic's Magazine*, Vol. 68) describes several systems submitted to the commission for preventing the formation of smoke. One of these, commended by the commission, is that of C. Wye Williams, C. E., whose well-known "Treatise on the Combustion of Coal and the Prevention of Smoke" is exhaustive. The plan of Mr. Williams is to admit above the fire, atmospheric air through a number of small holes in front, and at the sides of the furnace. This plan has been used successfully by the writer in many cases, but somewhat modified

by heating the air by causing it to pass through the ash-pit into a hollow bridge wall in which a course of bricks near its top and next to the combustion chamber were laid in pairs, on edge, about ¼ of an inch apart, without cement between them, thus forming several apertures of ¼ x 2½ inches, through which the air emerges and mixes with the gases. The admission of air to the chambered bridge-wall was controlled by a damper in the ash-pit.

All the authorities agree in this dictum: After a fresh supply of fuel is put upon the grates, air *must* be admitted above them and its volume regulated by a damper.

Mr. Robert Wilson, C.E., inspector for the Manchester Steam Users' Association, in his "Treatise on Steam Boilers," remarks on page 254: "In burning semi-bituminous steam coals a considerable quantity of fresh air is required for combining with the hydrocarbons above the layer of coal, and must be admitted directly to the gases at the furnace front, or at the bridge, or which is perhaps better, at both. Whichever plan is adopted, too great care cannot be taken to admit the air in small jets by perforations, or other means, especially when its direction is parallel with the current of gases. This ensures a better mixing, and prevents to a very material degree the undesirable cooling effect of introducing a large volume of cold air in one place, which is liable to defeat the end for which it is introduced."

Much depends on the fireman. No "hard and fast" rule can be applied to the manner in which he should manage his fires, but he must learn from experience the working peculiarities of the grates, flues, stack, etc., and adapt his methods to them.

Thomas Box, in his "Practical Treatise on Heat," says in paragraph 111: "It will also be seen in every case the proper regulation of the damper is a matter of extreme importance, and that nice adjustment is necessary to produce the best effect, too much or too little air causing a great loss of fuel; an intelligent stoker (fireman), without any knowledge of the theory, finds by experience the height of damper with which he can do the work with the least fuel; if the work varies he

watches and adjusts the damper accordingly, and such a man should have more consideration and better wages than he usually receives."

Perhaps the most effective way to abate the smoke nuisance will be, not by legislative enactment, imposing a penalty, as in the towns of Great Britain, but to convince users of bituminous coal who permit smoke to appear at their chimney tops that it is an unmistakable evidence of wasteful firing, for which the remedy is in their own hands. Frequent, moderate replenishment of coal, evenly spread over thin fires already glowing, and a sufficiency of fresh air admitted to the furnace above the fires, will prevent the evil. The resulting material reduction in the amount of the coal bills will prove to be a most convincing argument, and the emission of smoke from stacks will be an evil of a past era.

PROF. H. W. SPANGLER:—Many furnaces are run in a very uneconomical way, and in many places where smoke-consumers, so-called, have been introduced, the efficiency of the combination has been largely increased. It is perfectly safe to say that in all such cases, even without the use of smoke-consumers, the efficiency might have been largely increased.

The value of smoke-consumers, as such, to the owner of a plant kept in proper shape is practically nothing. That is, a furnace hand-fired, having a large fire surface, with the coal properly coked before being pushed over the fire, will emit large quantities of smoke when the coal is green. The value of this smoke, if it could all be entirely burned, has been shown to be less than 2 per cent. of the heating value of the coal. That is, practically, the smoke is valueless to the owner of the plant.

In many cases when boilers are inefficiently run, the self-interest of the owners will make it easily possible to prevent the formation of smoke by persuading them or forcing them to put in such apparatus as will, for their sakes, make their plants more economical, and for ours, do away with the smoke.

In those cases where, because of insufficient furnace area, very large quantities of coal must be burned per square foot of grate surface to develop the power of the boiler, no device, short of rebuilding the boiler, will reduce appreciably the for-

mation of smoke, and in many cases where attendants are apparently at fault, closer examination will show that the apparatus for burning the coal—the furnace, as distinct from the boiler which absorbs the heat—is at fault.

This question is as old as the burning of soft coal; it has been investigated by all sorts of commissions and the technical papers are filled with descriptions of devices for doing this particular work. All these have resulted in little towards correcting the evil, because it is cheaper not to bother about the smoke. When these devices have been used it is because they are supposed to be heat savers, not smoke preventers.

Nevertheless, the black soot is a nuisance; the major portion can be prevented in many existing stationary plants, and new plants can be erected so that the future annoyance from this cause can be reduced to a minimum.

In the case of locomotives the story is quite different, and probably the only feasible method of practically doing away with the smoke is to stop using soft coal, although care in firing will probably reduce the quantity greatly. Even if this were done the annoyance would by no means be over. The distance to the top of the smoke-stack is so small that the products of combustion, which will always carry dirt and coal particles with them, will annoy persons living along the line of the railroads. The odor of the hot products of combustion from anthracite is almost as unpleasant as are those from soft coal. Steps should be taken to insure that all locomotives constantly in use in the city should be practically smokeless.

No attempt should be made to prevent the using of soft coal, and as each case needs separate treatment, judicious advice will, in many cases, accomplish all that is desired. When new plants are to be installed, or old ones extended, for the use of soft coal, the plans should be approved by the proper official before they are built. Sufficient time should be allowed before any compulsion is attempted.

MR. A. FALKENAU:—One of the main objections urged to firing so as to give smokeless products of combustion, is the danger of loss of heating effect by the use of too great an excess of air. It is, therefore, desirable to mark the point

where the combustion is most nearly perfect; that is, where neither smoke is produced nor an unnecessary amount of heated air passed up the chimney.

The Arndt econometer, an instrument for continuously recording the percentage of carbonic acid in the escaping flue gases, is used to some extent in Europe with apparently very satisfactory results. It appears that in some cases where the instrument was applied, the amount of carbonic acid indicated was only 4 to 5 per cent. In these cases the alteration of the grates and furnaces brought the percentage up to 12 or 14.

With such an instrument in use the control of the furnace becomes much simplified, and the point at which the smoke just disappears could easily be recorded. The instrument is simple in construction, being practically a pair of scales, having an inverted glass bell on one arm and counterweight on the other. The flue gases flow continuously in and out from the inverted jar, and any variation in density is at once read from a pointer traversing a scale, graduated so as to indicate the percentages of carbonic acid up to the theoretical 21 per cent.

If instruments for registering the conditions of combustion had received the same attention and development as those used in the control of steam, it is likely that the satisfactory solution of the smoke question would be much nearer realization. If furnaces and flues were regularly equipped with water gauges, pyrometers and econometers, a more intelligent class of firemen would soon be created.

MR. F. LYNWOOD GARRISON:—When fresh bituminous coal is thrown upon a hot fire a destructive distillation takes place, resembling somewhat that which is effected in heating such fuel in a retort when making coal gas for illuminating purposes. In other words, its volatile constituents are driven off. These consist essentially of certain combustible gases, the moisture and the sulphur compounds. The latter two constituents are extremely variable, and their consideration is not necessarily essential to this discussion. It is the volatile combustible gases which give us trouble and are the essential cause of smoke; that is, the black, objectionable smoke. The amount of these volatile gases in the coal varies, as a general

average, from 12 to 30 per cent. They consist of marsh gas (CH_4), ethylene (C_2H_4), some acetylene (C_2H_2), benzol and other hydrocarbons, together with variable quantities of carbon monoxide (CO). Now even under the worst possible conditions some of these gases will be consumed, and only a portion will be available for the purpose of producing smoke. The most competent investigators have found under fairly good conditions that a very small amount of heat is lost even when a large proportion of these gases escape unburnt, which is especially noteworty as individually and collectively their calorific power is great. Scheurer-Kestner found, even when a thick black smoke was produced by limiting the air supply, that the loss of heating effect due to the smoke amounted to only 1½ per cent. and an increase of air reduced this ½ per cent.*

It is evident that there is no notable economy to be gained in consuming the smoke, and that the cost of the appliances necessary to effect its consumption would more than offset the increase in heat thereby derived.

There are two reactions by which the formation of smoke may be explained. It is probable they take place simultaneously in most cases, and individually under certain conditions. Where the fire is very hot, the affinity between the hydrogen and carbon decreases; thus when ethylene (C_2H_4) is passed over a highly heated surface, a portion of the carbon (black smoke or lampblack) is deposited and a new gaseous hydrocarbon is formed. Then again it would seem that under other or perhaps similar circumstances, marsh gas (CH_4) reduces CO_2 with the separation of carbon (black smoke).

Deville showed by the following experiment how hydrocarbon gases were dissociated by sudden cooling. A curved copper tube was introduced into the gaseous current just behind the fire bridge, both ends of the tube projecting outward. When the tube was empty it soon attained the temperature of the gases at that point; if filled, however, with water allowed to circulate so as to keep it cool, it quickly became

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* *Revue Scientifique*, April 7, 1888, p. 420.

coated with soot produced by the dissociation of the gases. Precisely the same thing takes place when we hold a cold plate in the ordinary illuminating gas flame. Likewise, everyone has noticed at the top of a chimney, that the escaping gases often leave a clear space for a few inches, then burst into a yellowish flame which, as it arises and comes further into contact with the cold atmospheric air, turns into black smoke.

The question before us is how to avoid this smoke by burning the furnace gases before they can become dissociated. It is plain, that smoke is either the result of an insufficient air supply, or an excess thereof at too low a temperature.

The effectual means of preventing the formation of this objectionable black smoke are limited to two classes of appliances. A third might, perhaps, be included in the indirect, though, perhaps, most effectual, system of converting the carbon of the coal into gas, the volatile carbon into the combustible gases I have mentioned, and the fixed carbon or coke into water gas by means of steam; the gases thus generated being burnt under the boilers or used directly to generate power in gas engines.

The first system to avoid smoke is to supply the fuel and air in regular and constant quantities by mechanical firing or automatic stoking. This method is fairly effectual, and of late years has been much improved. Its economy, from a business view, is, however, quite another matter, and is determined by a variety of conditions.

The second system is to promote so thorough, quick and intimate a mixture of the gases and air as to produce complete combustion. This is often effected by the use of a steam jet, which, while doubtless effective in some cases, is certainly the means of a great loss of heat.

When a furnace is hand-fired, the fresh fuel, added intermittently, requires more than double the amount of air it did the moment before; here the air supply must also be intermittent, since an excess of air is as bad as an insufficiency; that is, the fluctuations of the air supply must be made to coincide with those of the fuel. It would seem that these conditions can only be met by very skilled firemen, and even then the

results leave much to be desired in the ordinary run of boilers, etc. The prevention or absence of smoke does not necessarily prove perfect combustion of the fuel. It is sometimes possible to prevent smoke by greatly limiting the supply of air, in which case a large portion of the potential of the coal may ascend the chimney in the form of highly combustible and invisible CO, entailing an enormous loss of heat.

MR. JAY M. WHITHAM [Correspondence]:—The proper method of preventing smoke is not to form it. Smoke-consumers *per se* do not exist. Smoke is formed from a volatile coal during the period of coking, and because either enough air for thorough combustion is wanting as the gases are distilled, or because this air is not properly diffused, or because the temperatures are unfavorable for combustion.

From a commercial standpoint, smoke, though unsightly and annoying in many ways, is no great loss in combustion, seldom exceeding one-third of 1 per centum of the fuel burned. When conditions favorable to the formation of smoke exist, the efficiency of the furnace is generally low, and a more or less serious commercial loss takes place, due to the non-combustion of invisible gases. Conversely, when the conditions are favorable for burning the invisible gases distilled from the coal, smoke formation takes place only in a slight degree.

To get good combustion, and hence not to form smoke, it is important to secure:

(1) A grate with from 40 to 70 per cent. of air openings.

(2) A draft strong enough to produce an active combustion, *i. e.*, not a smothered fire.

(3) A high furnace temperature.

(4) A roomy furnace, so that the gases may *linger* and have *time* for burning before traversing much of the heating (*i. e.*, refrigerating) surface of a boiler.

(5) To feed the fuel either regularly, as with a mechanical stoker, or lightly and at short intervals by hand-firing.

(6) To thoroughly understand the fuel to be burned, since the treatment most favorable for burning Cumberland coal will not be best suited to Reynoldsville coal, etc.

It is not necessary to expend a large sum in installation in

order to burn fuel with but trifling smoke formation. In hand-firing ordinary furnaces and ordinary boilers, but little smoke will be formed if the furnace be coaled lightly, through alternate doors. In this way but a part of the fire is covered at one time and the gases and air are heated by the remainder. The fire should not be sliced or broken up until the coking is effected. Openings in the front of the furnace, varying with the rate of combustion from ½ to 2 square inches per square foot of grate area, are a decided advantage, while but little gain results by the use of a split bridge.

In horizontal tubular boiler settings no special advantage results from the use of a refractory coking arch over the front of the grate, but its presence is desirable for a volatile coal burned under a water tubular boiler. When such an arch is used, of course the coal should be coked in front and then spread, the fires being from 10 inches to 14 inches thick in front, and from 4 inches to 8 inches thick behind.

The period of smoke formation need never be long when using mechanical stokers, if they are properly handled, and have sufficient area for the work required. Such devices are, however, costly in installation and also in repairs (the repairs per year often amounting to from $5 to $10 per square foot of grate, while the first cost is from $25 to $40 per square foot).

The Hawley Down-Draft Furnace is now being introduced in Philadelphia, and has been in operation elsewhere for years. I have made a number of careful tests of it, varying from ten to 132 hours. For thirty-four hours, observers, with stop watches, found that the smoke record was about as follows:

Stack clear	93 per cent. of the time
Faint gray color	4 " " " " "
Dark gray color	2 " " " " "
Black	1 " " " " "

Such a record means smokelessness. The furnace is high, while the stack gases are low in temperature. The combustion chamber is always incandescent, and the stack gases are practically devoid of unburned constituents, as shown by repeated analyses.

This furnace possesses all of the essentials for smokeless-

ness and good economy and does not require special skill in operation, but is expensive in installation, and may not be suited to all kinds of feed waters.

Mr. W. M. Stein [Correspondence]:—The pollution of air and water constitutes a serious problem in densely populated manufacturing districts; and the solution of this problem offers a wide field of investigation to the engineering and chemical professions. The question of the smoke nuisance is a very old and difficult one to handle, and numerous inventions have been patented in various countries to abate the same or reduce it to a minimum. Ordinances have been passed in all civilized countries against the smoke nuisance. A great fault of all ordinances which I have studied is that they are pointed exclusively against smoke from manufacturing establishments. Smoke arising from residences and small industrial establishments is, as a rule, not covered by the laws, and for this reason the laws are more or less insufficient or even unjust.

The aim of all large consumers of fuel is to avoid needless waste and the smoke usually connected therewith. Most modern works have availed themselves of apparatus giving the desired economy and practical smokelessness at the same time. Large furnaces can now be economically operated by any of the well-known systems of gas-firing. For large boiler plants, gas-firing is practicable, or automatic stokers may be used, provided that they are well designed. Well-prepared fuel of uniform size is necessary to obtain good results with automatic stokers.

On the continent of Europe several systems of coal-dust firing have been introduced with successful results. The fuel used is finely pulverized (80 meshes per inch), and this fine powder is ingeniously introduced into the fire-place. Practically, the theoretical amount of air required for complete combustion is admitted. The better systems of coal-dust firing are absolutely smokeless. The dust firing is already successfully employed for puddling, heating and crucible melting furnaces, as well as for boilers.

The city of Berlin uses a number of dust-firing apparatus in connection with some of the municipal boilers. As a whole,

there can be no doubt that large consumers of fuel can arrange their plants economically and smokeless. For locomotive firing in the city limits it would be advisable to use anthracite or coke as much as possible.

To abate the nuisance of smoke arising from domestic fireplaces and small industrial establishments is a much more difficult than from large establishments. As a rule, the fireplaces in dwellings and small industrial establishments are much less economical, and necessarily cause proportionately much more smoke.

Fortunately our city is so located that anthracite coal and coke can be had by the small consumer at reasonable prices. The smoke from these sources can be reduced to a minimum. Cheap fuel gas can be supplied to small consumers in cities located in the soft coal district, and the present state of the science of gas-making is such as to guarantee cheap gas for the future.

Personally, I am opposed to legislation for the regulation of the smoke nuisance, as it would be very difficult to pass laws to cover the subject perfectly without causing injury to many. I believe the question will solve itself through the necessity of economy.

Dr. W. H. Ford:—I do not wish to occupy time which may be turned to better advantage, but I would like to say that the discussion which has occupied two evenings has been thorough, comprehensive and conclusive. The results obtained have been definite, and indicate first, that the smoke nuisance exists to a considerable extent, although it is not so excessive as it might be, and as it will most certainly become in the course of time, unless some measures are introduced for its restriction. In the second place, it has been demonstrated, very satisfactorily, that the smoke nuisance is entirely unnecessary, as there are means of its prevention easily procured or adopted without entailing any hardship or great expense upon the owners of boilers. In the third place, it has been shown that by proper ordinances, requiring the application of apparatus and the proper management of firing, the smoke nuisance may be measurably controlled, if not entirely prevented.

It is much easier and much wiser to suppress this nuisance now, before it has become so very general, than to wait until it has grown to such proportions that any regulation aimed at its suppression will necessarily require an immense amount of reconstruction, and provoke formidable opposition.

The decision of the Institute to collect and print the valuable data presented at this discussion, which has been participated in by experts from different parts of the country, and by men who have practical knowledge of mechanical engineering, will be of great advantage in consummating the object for which these meetings have been called, namely, to suggest and endorse a reasonable plan for suppressing the smoke nuisance. The collected data and arguments—always useful for reference—together with the support of the Franklin Institute, will go far toward furthering the efforts that are being made by the authorities and citizens in removing from our fair city a nuisance which is not only annoying, but, in many cases, positively detrimental to the public health.

THE PRESIDENT requested Mr. Outerbridge to close the discussion.

MR. OUTERBRIDGE:—Owing to the lateness of the hour, I will omit the experimental demonstration I had prepared for the purpose of showing how great a smoke a small amount of bituminous coal may produce, and how easy it is to thoroughly consume this smoke when suitable conditions are provided therefor.

It is not at all surprising to me that the gentleman from Reading (Mr. Sternbergh), who spoke this evening, found that the introduction of "a large quantity of air" above his fire failed to consume the smoke. Excess of air (which contains 77 per cent. of inert nitrogen) is worse than useless; for smoke has a flashing point, just as petroleum has a flashing point, but a much higher temperature is requisite to cause smoke to burst into flame.

In order to successfully consume smoke, it is necessary that the air with which it comes in contact should be, at all times, heated up to the point, which I have ventured to call "the flashing point," of smoke. An excess of air over the required amount is wasteful of heat.

A familiar and simple illustration of the flashing point of smoke is afforded in the case of a match-stick or other small piece of wood held above the chimney of an Argand burner. The heat causes the wood to char, the smoke rises with the current of hot air and gases, and, being heated up to the flashing point of finely divided carbon, takes fire and burns several inches above the wood.

Soft coal differs from anthracite, mainly in the fact that it carries from 25 to 35 per cent. of "volatile matter," consisting of hydrocarbon and other gases, which pass off invisibly, when the coal is heated to a moderate degree, and of carbon in fine particles, which escape in the visible form of smoke or soot. The weight of the smoke is comparatively trifling, and its fuel value is therefore small, but the presence of smoke is the visible evidence of imperfect combustion of the more valuable invisible gases.

The necessity of frequently opening the furnace doors, when soft coal is fed by hand, is largely responsible for the production of smoke, because the in-rush of cold air reduces the temperature in the flame chamber temporarily below the flashing point—or combustion point—of finely divided carbon. The smoke is therefore carried out unconsumed and discharged into the atmosphere, thus often creating a smoke nuisance.

There are, as we know, quite a number of mechanical appliances which have been devised for the automatic feeding of coal to stationary boilers and for effecting the complete combustion of smoke. Some of these appliances are simple in design others more complicated; some will burn any kind of cheap bituminous slack without visible smoke appearing at the chimney top, others will not do so under all conditions.

Now that the principles of smokeless combustion of bituminous coal are so well understood and are capable of application to all stationary boilers, there is surely no reason for the encouragement of the growth of a smoke nuisance in this city by failure to provide suitable restrictions or regulations. For these reasons I think it is clearly within the domain of this Institute to record its sentiments in favor of some practicable

legislation, and I have therefore prepared a few resolutions which I will present for your consideration:

WHEREAS, The Board of Health of the city of Philadelphia has requested the Franklin Institute to investigate the question of smoke prevention and to offer practical suggestions relative thereto; and

WHEREAS, The use of bituminous coal for fuel is increasing in this city and is likely so to continue in the future; and

WHEREAS, It appears from testimony of scientists and expert mechanics, presented at this meeting, by invitation of this Institute, that it is practicable to burn bituminous coal in stationary boilers and furnaces without creating a smoke nuisance;

Therefore be it Resolved, That it is the sense of this meeting that the continuous or frequent discharge of dense black smoke from the combustion of bituminous coal is unnecessary and should not be permitted within the city limits.

Resolved, That a copy of these resolutions be sent to the Mayor, to the President of the Board of Health and to the Presidents of City Councils.

After some discussion, the foregoing preamble and resolutions were referred to the Board of Managers, with the request to report to the next stated meeting of the Institute on the propriety of their adoption.

APPENDIX.

As a matter of general interest bearing on the subject of the foregoing discussion and for convenience of reference, there is hereto appended copies of the municipal ordinances for the regulation of the smoke nuisance, now in force in a number of cities of the United States. W.

SMOKE ORDINANCES.

CHICAGO, ILL.

SECTION 1650. The emission of dense smoke from the smoke-stack of any boat or locomotive, or from any chimney anywhere within the city, shall be deemed and is hereby declared to be a public nuisance, provided that chimneys of buildings used exclusively for private residences shall not be deemed within the provisions of this ordinance.

SEC. 1651. The owner or owners of any boat or locomotive engine, and the person or persons employed as engineer or otherwise, in the working of the engine or engines in said boat or in operating such locomotive, and the proprietor, lessee or occupant of any building who shall permit or allow dense

smoke to issue or be emitted from the smoke-stack of any such boat or locomotive, or the chimney of any building within the corporate limits, shall be deemed and held guilty of creating a nuisance, and shall for every such offense be fined in a sum not less than $5 nor more than $50.

SEC. 1652. It shall be the duty of the Commissioner of Health and the Superintendent of Police to cause Sections 1650 and 1651 of this article to be enforced, and to make complaint against and cause to be prosecuted all persons violating the same.

CINCINNATI, O.

SECTION 1. Be it ordained by the Board of Legislature of the city of Cincinnati, that the emission of dense smoke from the smoke-stack of any boat or locomotive, or from any chimney anywhere within the city, shall be deemed and is hereby declared to be a public nuisance; *provided* that chimneys of buildings used exclusively for private residences shall not be considered within the provisions of this ordinance.

SEC. 2. The owner or owners of any boat or locomotive engine, and the person or persons employed as engineer or otherwise in the working of the engine or engines in said boat, or in operating such locomotives, and the proprietor, lessee or occupant of any building who shall permit or allow dense smoke to issue or be emitted from the smoke-stack of any such boat or locomotive, or the chimney of any building within the corporate limits, shall be deemed and held guilty of creating a nuisance, and shall for every such offense be fined in a sum not less than $5 or more than $50.

SEC. 3. It shall be the duty of the Supervising Engineer to cause the enforcement of this ordinance, and to make complaint against and cause to be prosecuted all persons violating the same; and in so doing he shall be assisted by the Superintendent of Police and the Health Officer, and their respective departments.

SEC. 5. This ordinance shall take effect and be in force from and after the earliest period allowed by law.

CLEVELAND, O.

SECTION 1. Be it ordained by the Council of the city of Cleveland that the emission of dense smoke from any chimney anywhere in the city, or from the smoke-stack of any boat, locomotive or stationary engine or boiler within the limits of the city of Cleveland shall be deemed and is hereby declared to be a public nuisance.

SEC. 2. That the emission into the air of any noxious gases or vapors or offensive odors from any manufactory, building or premises within the limits of said city, injurious to health or annoying to the inhabitants of said city, or any part thereof, shall be deemed and is hereby declared to be a public nuisance.

SEC. 3. That the owner, lessee, engineer, fireman, or other person or employé having charge or control of, or operating any boat, locomotive or stationary engine, or boiler, manufactory, building or premises, within the corporate limits of said city, who shall permit or cause dense smoke to issue from any smoke-stack or chimney thereof, or connected therewith; or any owner, lessee, or other person or employé having charge or control of, or operating any building, manufactory, building or premises within the said corporate

limits, who shall cause or permit any noxious gases or vapors, or offensive odors, as described in Section 2 of this ordinance, to issue from such manufactory, building or premises, shall be deemed and held guilty of creating a public nuisance, and upon conviction thereof in the police court of said city, shall be fined not less than $50, nor more than $100 for each and every such offense.

SEC. 4. That it shall be the duty of the Health Officer of the Department of Police to enforce the provisions of this ordinance, and he shall, upon his own motion, or upon the complaint or information of any resident of said city, commence proceedings in the police court against any person for violating any of its provisions, whenever, in the judgment of said Health Officer, facts warrant such proceedings.

SEC. 5. That the words "owner," "lessee" and "person" occurring in this ordinance in the singular number shall include the plural; and they shall each be construed so as to embrace corporations, or partnership associations, as well as natural persons.

SEC. 6. That this ordinance shall take effect and be in force from and after its passage and legal publication.

PITTSBURGH, PA.

An ordinance to regulate and suppress the production and emission of smoke from bituminous coal; and to provide penalties for the violation thereof in certain districts of the city.

SECTION 1. *Be it ordained and enacted by the City of Pittsburgh;* That from and after September 1, 1892, the emission of smoke from bituminous coal, or escape of such smoke from any chimney or smoke stack used in connection with stationary boilers within the limits of the following defined district: Beginning at Miltenberger Street and Second Avenue; thence along the northern curb of Second Avenue to the eastern line of the city; thence along said city line to the Allegheny Valley Railroad; thence along the Allegheny Valley Railroad to the Sharpsburg Bridge; thence along Bridge Street to Butler Street; thence along the southern curb of Butler Street to Penn Avenue; thence along the south curb of Penn Avenue to Thirty-third Street; thence along Thirty-third Street to Center Avenue; thence by Center Avenue to Devilliers Street; thence by Devilliers Street to Dinwiddie Street; thence by Dinwiddie Street to Fifth Avenue; thence by Fifth Avenue to Miltenberger Street; thence by Miltenberger Street to Second Avenue, at the place of beginning, shall be deemed and is hereby declared to be a public nuisance.

SEC. 2. That it shall be unlawful for any corporation, co-partnership or individual owning, controlling or using any chimney or smoke-stack used in connection with stationary boilers within the limits of the district, as provided in Section 1, to allow, suffer or permit smoke from bituminous coal to be emitted or escape therefrom.

SEC. 3. Any corporation, co-partnership or individual who shall or may allow, suffer or permit smoke from bituminous coal to be emitted or to escape from any chimney or smoke-stack used in connection with stationary boilers within the limits of the district, as provided in Section 1 as aforesaid, shall, in addition to any and all law requiring the abatement of nuisances, forfeit and pay to the city of Pittsburg for every such offense a sum not less than $10 or

more than $50, to be recovered before any Alderman of the county of Allegheny, or any Police Magistrate of the city of Pittsburg as debts of like amounts are now recoverable.

SEC. 4. No discrimination shall be made against any device or method which may be used which will accomplish the purpose of this ordinance in relation to the said matter.

SEC. 5. The Chief of the Department of Public Works of the city of Pittsburgh is hereby empowered to enforce the provisions of this ordinance.

OHIO STATE ORDINANCE.

An Act to Provide for the better Protection of Human Life against Fire, and Regulate the Construction and Management of Steam-Boiler Furnaces in Cities of the First and Second Grades of the First Class.

SECTION 4. Every steam-boiler furnace used within the corporate limits of any city of the first grade of the first class shall be so constructed or altered, or have attached thereto such sufficient smoke preventives as to produce the most perfect combustion of fuel or other material from which smoke results, and so as to prevent the production and emission of smoke therefrom so far as the same is possible. And any person, or persons, association or corporation, being the owner or lessee, or having control of any such steam-boiler furnace (who) shall use or allow the use of any such steam-boiler furnace which shall not be so constructed, or if already constructed at the time of the passage of this act, shall not be so altered, or shall not have attached thereto such efficient smoke preventives as to produce the most perfect combustion of fuel or other material from which smoke results, and so as to prevent the production and emission of all smoke therefrom so far as the same is possible, or shall fail to keep such steam-boiler furnace for the prevention of smoke, and such smoke preventives in good and efficient order and operation, shall be subject to a fine of not less than $20 nor more than $50 for the first offense, and for each subsequent offense shall be fined not less than $50 nor more than $100. And no steam-boiler furnace shall hereafter be constructed in any city of the first grade of the first class, except in accordance with the requirements of this section, under the penalty of $50 for each offense.

SEC. 5. Every person having charge of the igniting, making, stoking, feeding or attending any such furnace and any smoke preventives attached thereto in good and efficient order and use, shall see that the least possible smoke shall be produced and emitted therefrom, and any such person who shall fail or neglect to so ignite, make, stoke, feed or attend such furnace fire that the least possible smoke shall be produced or emitted therefrom, or shall fail or neglect to keep such furnace or smoke preventives attached thereto in good and efficient order and use, or shall hinder or disarrange any such furnace or smoke preventives attached thereto, shall be subject to the payment of a penalty of not less than $20 nor more than $50 for the first offense, and not less than $50 nor more than $100 for each subsequent offense.

SEC. 6. The mayor of the city in every city of the first grade of the first class shall appoint a person of suitable qualifications as Supervising Engineer, who shall hold his office for the term of two years, from and after the date of his appointment, and until his successor is appointed and qualified; and he shall have authority to supervise and require all steam-boiler furnaces in such

city of the first grade of the first class to be constructed, or if already constructed, to be so altered or have attached thereto such efficient smoke preventives, so as to produce the most perfect combustion of the fuel or other material from which smoke results, and so as to prevent the production and emission of all smoke therefrom so far as the same is possible, and he shall further have authority to supervise the igniting, making, stoking, feeding and attending such steam-boiler furnace fires; and he shall have further authority in the performance of the duties of his office, to enter any steam-boiler or engine room, or any building not occupied exclusively as a private residence, and any person or persons hindering or obstructing him in the performance of such duties shall be subject to a fine of not less than $20 nor more than $50, or imprisoned in the workhouse for a period not exceeding thirty days.

SEC. 9. The penalty for any violation of the provisions of this act, not otherwise specially provided for, shall be not less than $20 nor more than $50 for the first offense, and not less than $50 nor more than $100 for each subsequent offense.

SEC. 10. All acts or parts of acts inconsistent or in conflict with this act, be and the same are hereby repealed.

SEC. 11. This act shall go into effect and be in force from and after its passage.

ST. LOUIS, MO.

An ordinance declaring the emission of dense black or thick gray smoke to be a nuisance, and to provide for the suppression thereof.

Be it ordained by the Municipal Assembly of the City of St. Louis, as follows:

SECTION 1. The emission into the open air of dense black or thick gray smoke within the corporate limits of the city of St. Louis, is hereby declared to be a nuisance. The owners, occupants, managers or agents of any establishment, locomotives or premises from which dense black or thick gray smoke is emitted or discharged, shall be deemed guilty of a misdemeanor, and, upon conviction thereof, shall pay a fine of not less than $10 nor more than $50. And each and every day wherein such smoke shall be emitted shall constitute a separate offense.

SEC. 2. This ordinance shall take effect at the expiration of six months after its approval by the Mayor.

Approved February 17, 1893.

An ordinance authorizing and providing for the making of regulations limiting and defining permissible smoke emissions, and for the testing of smoke-prevention devices, and for the making of such tests and experiments as may be deemed advisable with a view to the abatement or suppression of the smoke nuisance.

Be it ordained by the Municipal Assembly of the City of St. Louis, as follows:

SECTION 1. The President of the Board of Public Improvements is hereby authorized and directed to appoint, with the approval of the Mayor, a commission composed of three competent persons, who shall not be directly or indirectly interested in the manufacture, sale or construction of any furnace

or other article having practical relation to the production or prevention of smoke. Said commission shall ascertain by a thorough canvass of the city and report to the Board of Public Improvements within four months after their appointment, the conditions and liabilities under which manufacturing and other parties cannot wholly or reasonably prevent the occasional production and emission of dense visible smoke. Such ascertained conditions and liabilities, when approved by the Board of Public Improvements and Mayor, shall be published, and thereafter shall constitute instructions to guide and limit the officials charged with the enforcement of smoke supression ordinances. And it shall be a valid and sufficient defense against any complaint that the offense charged comes within such recognized conditions and liabilities.

Said commission shall conduct and make practical tests of all devices for the prevention or suppression of smoke which shall be submitted to them, in accordance with the conditions hereinafter set forth, and shall prepare detailed reports, stating the facts and conclusions based thereon, as to the efficiency of such device, the conditions of its successful operation and the limitations to its efficiency. Said report shall be made promptly when any test is completed, to the Board of Public Improvements, which report may be rejected by said Board if found to be unfair or untrue. If accepted by said Board, the report shall be published for the information of the public.

Said commission shall also be called upon by the President of the Board of Public Improvements to make such tests and experiments as may, in his judgment, be needed to determine the applicability of special or smokeless fuels to domestic, locomotive or other uses, with a view to the abatement or suppression of smoke, and shall prepare detailed reports of the results, together with such conclusions and recommendations as in their judgment may be warranted by the facts, said reports to be made promptly and printed for the information of the public.

SEC. 2. The commissioners authorized by the preceding section shall receive, in compensation for their services in ascertaining, by a thorough canvass of the city, and reporting the conditions and liabilities of smoke suppression, the sum of $1,000 each, payable upon the certificate of the President of the Board of Public Improvements that such report has been made to and accepted by the Board of Public Improvements. For their services in conducting tests of devices and making reports thereon, they shall each receive the sum of $75 for each device tested and reported, and for conducting the special tests and experiments, as provided in the preceding section, $100 for each series of tests or experiments, together with a full report of the same. Said respective sums to be paid on the certificate of the President of the Board of Public Improvements, that the report of such test has been received and accepted by said Board.

Incidental and other necessary expenses for the above-described investigations shall be allowed and paid for as other expenses of the President of the Board of Public Improvements.

SEC. 3. Any party having, or claiming to have, a plan or device whereby smoke can be prevented or suppressed, and desiring to have the same subjected to a practical test and determination, may do so on the following conditions

(1) He or they shall notify, in writing, the President of the Board of Public

Improvements, that such a test is desired, and with such notice shall file a full and complete description of the device, with all necessary drawings to show its character, construction and mode of operation. Accompanying such notice shall be a certificate of the City Treasurer that there has been deposited with him to the account of the fund for testing smoke-prevention devices the sum of $400, and said sum of $400 shall absolutely become the property of the city of St. Louis, and no claim shall hereafter be made or allowed to refund the same or any part thereof; and upon the presentation of the Treasurer's certificate to that effect, the President of the Board of Public Improvements shall order the commission to make the test.

(2) The party or parties submitting a device shall erect the same at such place as the commission may approve, at their own cost and expense, under their own supervision, with such provisions for the attachment of instruments as the commission may require, and when fully ready shall deliver the premises and equipment to the commission.

(3) If, after test is begun, alterations or improvements are desired to be made, the party interested must proceed as if submitting a new plan or device, unless the several commissioners shall each consent to such alterations and waive all claim for compensation for a partial test.

SEC. 4. Whenever the Mayor shall be of the opinion that the public interest does not warrant the further testing and reporting on devices, under the authority of the city of St. Louis, he shall notify the President of the Board of Public Improvements to that effect, in which event the existence of the commission, hereby authorized, shall terminate when tests already in hand shall have been completed and reported as herein provided.

SEC. 5. When the commission created by the preceding sections of this ordinance shall have made its report as provided in Section 1, and shall have found that there are practicable methods of appliances by which the emission of black or thick gray smoke may be prevented, and such report shall have been approved as hereinbefore provided; and, also, when an ordinance declaring the emission of black or thick gray smoke to be a nuisance and to provide for the suppression thereof, shall have come into full force and effect, then the President of the Board of Public Improvements is hereby authorized and directed to appoint, with the approval of the Mayor, such inspectors, not exceeding three in number, as may be necessary to carry out the provisions of the following section of this ordinance. Said inspectors shall receive a salary of $100 a month each, payable monthly.

SEC. 6. The inspectors shall have a right to enter, in the performance of their duties, at reasonable hours, upon all premises other than dwelling houses occupied by less than four families or tenants. They shall collect evidence of the facts in the case of the violation of this ordinance, declaring the emission of black or thick gray smoke to be a nuisance and to provide for the suppression thereof, and, with the approval of the President of the Board of Improvements, shall report the same to the City Attorney for prosecution. The inspectors shall be guided in the performance of their duties by instructions given by the Board of Public Improvements from time to time.

Approved February 17, 1863.

DETROIT, MICH.

REVISED ORDINANCES, CITY OF DETROIT, 1895.

Chapter xc. Prevention of Smoke Nuisance, Approved June 8, 1887.

SECTION 1. The emission from any chimney or smoke-stack within the city, of dense smoke, or smoke containing soot or other substance in sufficient quantity to permit the deposit of such soot or other substance on any surface within the corporate limits of the city, shall be deemed, and is hereby declared, a public nuisance.

SEC. 2. Any owner, agent, lessee, or manager of any building, boat, locomotive or other structure in the city of Detroit, who shall cause or permit dense smoke, or smoke containing soot or other substance as above, to be emitted from such structure, or from any other place which said soot or other substance shall damage the property or injure the health of any person, or shall especially annoy the public, shall, on the complaint of any person so damaged or injured, as aforesaid, or on complaint of any citizen or officer of the city, in case of especial annoyance, be liable for each and every such offense to a fine of not less than $10 nor more than $100, or to imprisonment in the House of Correction not less than ten days nor more than thirty days, or both such fine, or imprisonment in the discretion of the Court: *Provided*, That the provisions of this ordinance shall not apply to buildings used exclusively for private residences or to steamboats.

MILWAUKEE, WIS.

An ordinance to prohibit the emission of dense smoke from the smoke-stack of any boat or locomotive, or from any chimney within the limits of the city of Milwaukee.

The Mayor and Common Council of the City of Milwaukee, do ordain as follows:

SECTION 1. The emission of dense smoke from the smoke-stack of any boat or locomotive, or smoke-stack anywhere within the limits of the city of Milwaukee, shall, from and after the date when the provisions of this section shall take effect, be deemed and is hereby declared to be a nuisance, provided that chimneys of buildings used exclusively for private residences shall not be deemed within the provisions of this ordinance.

SEC. 2. The owner or owners of any boat or locomotive engine, and the person or persons employed as engineer or otherwise in the working of the engine or engines in said boat, or in operating such locomotive, and the owner, lessee, or occupant of any building who shall permit or allow dense smoke to issue or be emitted from the smoke-stack of any chimney or smoke-stack within the said limits shall be deemed guilty of creating a nuisance, and shall, for every such offense, be fined not less than $5 nor more than $50, or punished by imprisonment in the House of Correction for not more than sixty days. Every day which said nuisance shall continue shall be deemed a separate offense.

SEC. 3. Hereafter before approving plans and specifications for the erection of any business building or factory within the limits aforesaid, it shall be the duty of the inspector of buildings of the city of Milwaukee to

see that proper provision is made in said plans and specifications to prevent the emission of dense smoke from the chimney of said building.

SEC. 4. It shall be the duty of the Commissioner of Health and the Chief of Police to cause Section 2 of this ordinance to be enforced, and to cause complaint to be made against all persons violating the same.

SEC. 5. This ordinance shall take effect and be in force from and after the first day of January, A.D. 1898, except that the provisions of Section 3, thereof shall be in force from and after its publication.

Passed February 3, 1896.

PHILADELPHIA, PA.

Copy of ordinance submitted to Councils January 1, 1894. (Never acted on.)

An ordinance to prohibit the firing or running of locomotive engines or the firing of stationary or portable boilers emitting dense smoke, the result of imperfect combustion of soft or bituminous coal, within the city limits, and to declare same a public nuisance.

SECTION 1. The Select and Common Councils of the City of Philadelphia do ordain: That the firing or running of locomotive engines, or the firing of stationary or portable boilers emitting dense smoke, the result of imperfect combustion of soft or bituminous coal, anywhere within the incorporated city, shall be deemed and is hereby declared a public nuisance.

SEC. 2. The owner or owners of any locomotive engine, or stationary or portable boiler, and the person or persons employed as engineer or otherwise in operating such locomotive or stationary or portable boiler, who shall permit and allow dense smoke, resulting from the imperfect combustion of soft or bituminous coal therein, to issue or be emitted from the smoke-stack of any such locomotive or stationary or portable boiler, within the corporate limits, shall be deemed and held guilty of creating a public nuisance, and shall for each such offense be liable to a penalty of $50, to be recovered in the manner that penalties for breach of ordinance are now by law recoverable.

SEC. 3. It shall be the duty of the Director of the Department of Public Safety to enforce the provisions of the ordinance, and to make complaint and and cause to be prosecuted all persons violating the same.

This ordinance shall take effect and be in force from and after January 1, 1894.

MINNEAPOLIS, MINN.

Amending an ordinance entitled "An ordinance declaring the emission of dense smoke within the City of Minneapolis a public nuisance, and prohibiting the same," approved February 16, 1894.

The City Council of the City of Minneapolis do ordain as follows:

SECTION 1. That an ordinance entitled "An ordinance declaring the emission of dense smoke within the City of Minneppolis a public nuisance and prohibiting the same, approved February 16, 1894, be and the same is hereby amended so as to read as follows:

SEC. 1. The emission of dense smoke from the smoke-stack of any locomotive or engine, or from the smoke-stack of any stationary engine, or from the smoke-stack or chimney of any building anywhere within the City of

Minneapolis shall be deemed, and is hereby declared to be a public nuisance and is hereby prohibited.

SEC. 2. The owner or owners of any locomotive engine and the general manager, superintendent, yard-master or other officer of any railroad company having charge or control of the operation of any locomotive engine, and the person or persons employed as engineer or fireman in operating such locomotive engine, who shall cause, permit or allow dense smoke to issue or be be emitted from the smoke-stack of any such locomotive engine within the City of Minneapolis, shall be deemed and held guilty of creating a public nuisance, and of violating the provisions of this ordinance.

SEC. 3. The owner, lessee or occupant of any building, and the fireman, engineer, or any other person having charge or control of any furnace or stationary engine who shall cause, permit, or allow dense smoke to issue or be emitted from the smoke-stack or chimney connected with any such furnace or stationary engine within the city of Minneapolis, shall be deemed and held guilty of creating a public nuisance and of violating the provisions of this ordinance.

SEC. 4. Any person or persons violating the provisions of this ordinance shall, upon conviction thereof before the Municipal Court of said city, for every such offense, be punished by a fine of not exceeding $100, and may be imprisoned until such fine is paid, not exceeding ninety days.

SEC. 5. It shall be the duty of the Commissioner of Health and Superintendent of Police to cause this ordinance to be enforced and to cause to be prosecuted all persons violating the same.

SEC. 2. This ordinance shall take effect and be in force from and after its publication.

Passed September 25, 1895.

MECHANICAL AND ENGINEERING PROGRESS AS INFLUENCED BY THE MINING INDUSTRY. *

BY JOHN BIRKINBINE.

The Franklin Institute was organized seventy-three years ago, 'for the promotion of the mechanic arts," and advances in this direction have carried its members into all branches of applied science.

The appropriateness of an active section of the Institute devoted to discussing problems in geology, mineralogy, mining and metallurgy becomes evident when we consider the influences upon mechanical progress and upon all branches

*Opening address at the organization meeting of the Mining and Metallurgical Section of the Franklin Institute, April 28, 1897.

of engineering which the development of the mining and metallurgical industries has exerted.

The railroad would be little more than a suggestion for economical transportation without the possibility of substantial rails, bridges, cars or locomotives. The production of these and the tools used in their creation are in turn dependent upon the metallurgical processes which transform ores, fuels and fluxes into metal of commercial shapes, and the development of these processes has encouraged exploitations of mineral deposits in such manner and of such magnitude as to supply satisfactory raw materials at low cost—a result which has been attained by intelligent investigation on the part of geologists and mining engineers.

The railroad is merely used as an illustration, for similar statements could be introduced to suggest the primary dependence of all, or nearly all, of our industrial and commercial advancement, and many of our modern comforts, upon the geologist, the mineralogist, or the mining and metallurgical engineers.

Travellers passing through a section of this or any other siastic at the number of imposing mills and factories, and point siactic at the number of imposing mills and factories, and point with satisfaction to these evidences of development; and if a train is scheduled to arrive at an industrial center, when crowds of well-dressed artisans are going to or returning from their daily labor, the appreciation of the value of these industries to the workingman and to the State is emphasized. But journeys through mining districts, as a rule, offer fewer evidences of great achievements; for beyond the head and power-houses or the "breakers" of mines, stocks of mine timber, rows of miners' cottages, and, in some cases, great piles of mine refuse, there is little on the surface to indicate what is being accomplished; and it is only occasionally that the mine openings are located near enough together to permit of any considerable concentration of working forces. Even if the miners are seen *en route* to or from work, the division of labor into "shifts" of from eight to twelve hours each, and the necessity of lifting the miners in small companies from below the surface, usually pre-

vent any large assemblage of workmen. There are exceptional mining localities where a number of shafts are close together, and hundreds of men and boys may be seen at one time, but even in these instances the grime of the underground life has a tendency to detract from the effect upon the general observer.

As visitors enter shops or mills, the clatter of machinery and the rapid movement of workmen, or the glare of furnaces at manufacturing industries, is more impressive than the puffing of hoisting engines, the throb of pumps, the rumble of the tram at mines, or the smothered reverberation following a blast below ground. The flame and sparks belching from converters at a Bessemer steel works, and the movement of ladles, hot ingots, shifting engines, etc., give to the casual observer an idea of activity beyond that represented by a mine of great magnitude, and yet a mine of moderate size may give employment to as many men as a large iron or steel works.

Thousands of miners toiling deep in the earth's strata are not only lost to sight, but generally entirely forgotten by the public, until an Avondale fire, a Twin Shaft cave, or an explosion, sacrifices such a number of lives as to appall the community and direct attention to the work of the human mole.

If we fail in an appreciation of the extent of the mining industry we are equally at fault in recognizing the influence which it exerts upon our development. The utilization of 150,000,000 to 175,000,000 long tons of coal, annually won from American mines, for industrial and household purposes, may, perhaps, be approximately gauged; or we may measure the advance in wealth due to the exploitation of the minerals each year to produce 55,000,000 to 60,000,000 ounces of silver, 2,000,000 to 2,250,000 ounces of gold, 350,000,000 to 400,000,000 pounds of copper, 170,000 short tons of lead, 90,000 short tons of zinc, quicksilver to the amount of 36,000 flasks, more than 500,000 to 1,000,000 pounds of aluminium, 53,000,000 barrels of petroleum, 8,000,000 to 9,000,000 barrels of cement, 11,500,000 to 13,500,000 barrels of salt, clays valued at $10,000,000, $35,000,000 worth of building stone, $13,000,000 worth of natural gas, 12,000,000 to 14,000,000 pounds of

borax, 15,000,000 to 16,000,000 tons of iron ore, etc. But even this impressive array of figures does not convey a just idea of conditions, and few truly realize what has been and what is being done by the mining industry to advance our nation.

To assist in forming a conception of the progress for which the engineering profession and the mechanic arts are indebted to this industry, attention may be directed briefly to some of the achievements which may be justly credited to the underground exploitation of our mineral resources.

Mr. Eliot Lord, in his monograph, "Comstock Mining and Miners," writing of that section of the State of Nevada which has produced gold and silver to the value of $380,000,000, says: "Such is the nature of the region bordering upon the eastern slope of the Sierras, and such the character of its savage inhabitants, that forty years ago no territory in America seemed more unlikely to attract a swarm of colonists. Except along its northern boundary, there was nothing to tempt the entrance of the intrepid fur trader, and even the undaunted Jesuit missionaries contented themselves with maintaining the white crosses of their stations on its border line. Thus the outside world knew and cared to know but little of this broad and seemingly worthless tract, and the homes of the Basin tribes would have been secure from intrusion to this day had it not been for the discovery of the treasures hoarded up in the barren ridges and cañons. The train of emigrants which crossed the plains in the year 1849 had no eyes to see the possible riches of the land through which they were passing, for their faces were set steadfastly toward the glittering beacon beyond the Sierras."

The Comstock lode is selected as an illustration, because its development rapidly transformed a desert mountain region, distant from any settlement, into a populous business center, supplied with superb evidences of engineering skill. The character of the ore won was the inspiration which developed some of the best forms of crushing appliances; the depth of workings, the size of deposits, the quantity of water to contend with, and the extreme heat of the lower workings demanded the construction of superior hoisting, ventilating and pumping ma-

chinery; the "square set" system of timbering (without which many other deposits could not now be successfully exploited), the construction of a drainage tunnel which is world-famous, and other innovations, resulted from the developments on the Comstock lode. The demand for timber to sustain the underground workings encouraged the application of the water-flume 25 miles long as a means of transportation, and the necessity of a supply of potable water was met by the construction of one of the earlier pipe lines conveying water under enormous heads, for which the Western country is famous. It is stated that, to supply the timber used in the Comstock mine, 200,000 acres of woodland have been cut over.

The migration in 1849, of seekers for gold, opened up the wealth of California, and that State is entitled to credit for many advances in hydraulic engineering devised to maintain its mining industry. Immense dams, long and tortuous canals or flumes, the cutting away of great masses of earth by streams of water delivered through "Little Giants" under heavy pressure, the diversion of streams, so as to work their natural beds as placers, and the construction of impact water wheels, operating under heads of water which previously had been considered impractical, are some of the results of mine developments. Colorado may well share in this credit, for it has extensive mining tunnels, elaborate water-power installations, etc., but in that State the construction of railroads in deep cañons or over high mountain passes, to reach the mines and convey their output to market, is probably considered the most notable feature. Montana, Oregon, Arizona, Utah, and in fact the entire mountain and Pacific sections of our great West, present numerous instances of progress, due primarily to the development of mineral properties, and the mining industry is undoubtedly largely responsible for the early completion of our transcontinental railroads.

The exploitation of iron and copper ores of the Lake Superior region has been a most potent factor in the material advancement of that district, and in the development of the lake marine. The depth of these mines, the quantity of material handled, and the distance from points of consumption and

from fuel supplies, have inspired the mechanical engineer to design hoisting, pumping and concentration plants second to none, and the marine engineer to supply vessels of superior construction and equipment.

The "New South" also owes its present advanced position more to the exploitation of its mineral wealth than to any other feature.

Coming nearer home, we may properly ascribe the construction of the canal system and the earlier railroads to the necessity of conveying the output of our coal mines to market, and of handling economically in large volume raw materials to, and the products from, furnaces and mills, and the pre-eminence of Pennsylvania as an industrial State is directly traceable to the utilization of its stores of fuels, ores, stones and clays.

It is unnecessary to multiply illustrations of the influences which the development of mines has exerted upon the progress of the country, or to point to the many instances where the geologist, the mineral explorer or the mining engineer have been pioneers in opening up sections of our country which, without their energy and investigation, would have remained practically a *terra incognita* for decades. Nor are such illustrations confined to our own country, but of the world over the same story may be told.

Mr. George F. Kunz, in an interesting lecture before this Institute, lately detailed the story of the momentous results in the world's history, and the territorial changes, which were directly traceable to the discoveries of and the search for precious stones and metals, and he could have drawn similar conclusions from the efforts to operate or control the sources of the useful minerals.

The exploiting of mines, therefore, has not only called into play the ability and energy of the geologist and the mining engineer, but has demanded also the best efforts of the metallurgist, the mechanical engineer, the electrical engineer, the civil engineer and marine engineer, to supply drilling, hoisting, ventilating, pumping and beneficiating machinery, or appliances for handling and transporting the pro-

duct by land or water; and has called on the chemist for the analyses of minerals, metals or gases and for the production of explosives. These specialists have been able to accomplish the desired results by placing the execution of their plans in the hands of intelligent mechanics, and to such artisans we are indebted for many of the mechanisms which to-day make cheap mine handling and transportation possible, and which permit of transforming the materials won from the earth into forms applicable to general use.

It is only when one descends into mines and notes the great chambers dug out of the earth, the quantities of timber placed to support, as far as is possible, the weight of roof or hanging wall, the massive pumps which elevate enormous volumes of water from great depths, and the powerful hoisting and ventilating appliances, that the magnitude of the mining industry is appreciated. When he investigates further and notes the drills penetrating the hard rock, or the cutters channeling below the mass, or locomotives traversing the low, narrow drifts, operated by electricity or compressed air, generated at some distant point, the aid of the mechanic becomes apparent.

The dip compass, the prospecting drill, the sinking pump, the steam winch, the rock drills, the crushers, the coal cutters, the chutes and the tram cars; the framing of shafts, mine timber, head houses and breakers; the conveyance of steam, water, air or electricity for power in hoisting, tramming, pumping, etc.; the rails, locomotives, cars and loading bins; the shipping and receiving docks for coal and ore, and the vessels built for their transportation; the machinery of concentrators, breakers, the buddle rocker, the vanner, jig and stamps, etc.; the blast furnaces, converters and roll trains, with their motive powers, all represent developments in the mechanic arts. Therefore, the discussion of modes of occurrence of minerals, of methods of mining and processes of manufacture, which will form part of the transactions of this section, must result in "the promotion of the mechanic arts."

The influence of the mining industry can be demonstrated to have extended into all branches of the mechanic arts; and in an organization devoted to the advancement of these arts

there is a special and extended field to be covered by a Section devoted to geology, mineralogy, mining and metallurgy. As president of this Institute, I am gratified that the Section starts with such a flattering expression of interest, and can promise hearty co-operation in its work.

CHEMICAL SECTION.

Stated Meeting, Tuesday, May 18, 1897.

Dr. Jos. W. Richards, President, in the chair.

NOTES on LUCIUM.

By Waldron Shapleigh.

In May of last year I secured several samples of the so-called "lucium" which had been prepared by Dr. Leon Schützenberger, of Paris, and at the same time saw a report in which this chemist gave very fully the methods which he used in preparing it, and his conclusions regarding the same; also samples of the monazite sand used.

The methods he employed follow very closely those set forth in the patent of Mr. P. Barrière.

The monazite sand was a low-grade North Carolina sand, containing minerals rich in titanium, zirconium and yttrite earths, such as menaccanite, rutile, zircon crystals, samarskite, euxenite and xenotime, and it is probable that from the last three minerals the "lucium" is obtained.

On experimenting with a solution of the lucium nitrate, the ignited ash or residue I found to be of a dirty gray color, and nearly entirely soluble in hydrochloric and nitric acids even when diluted. This solution was clear and pink, and gave the absorption bands of erbium. As the time recommended by Mr. Barrière for digesting with the potassium sulphate for the separation of the cerite group seemed to me rather short, I saturated the solution with potassium sulphate in the cold

and allowed it to stand forty-eight hours, thereby obtaining a precipitate consisting of the cerite group, and in the solution, the yttrite group. Analysis showed:

Yttrite group oxides	93·98
Lanthanum, cerium, didymium oxides	3·74
Thorium oxide	1·07
Titanium, zirconium, potassium, sodium oxides, and sulphuric acid, not separated	1·21
	100·00

The oxides of the yttrite group after this thorough purification by potassium sulphate were of a light buff or yellow color, fully and completely soluble in dilute acids. Sodium hyposulphite did not give a precipitation in a fairly concentrated solution, nor was there any difficulty in making a partial separation of the erbium nitrate in the fused nitrates by Bahr and Bunsen's method. Although the quantity at my disposal was small, I obtained the erbium nitrate crystals and showed the possibility of this separation.

Regarding the precipitation with sodium hyposulphite, on which great stress is laid as a reaction, showing "lucium" to be a new element, if a solution of yttrite sulphates in a concentrated solution of potassium sulphate made by cold digestion is heated, a copious precipitation will ensue. Though not a perfect separation, yet advantage can be taken of this reaction in separating yttrium from erbium, and this reaction should be borne in mind when separating the cerite from the yttrite group, as some text-books recommend using hot saturated solutions. By doing so, some of the yttrium will be precipitated with the cerite group.

This action of heat on the double sulphate solution of the yttrite group, if it does form similar salts to the cerite group, I have not met with in the text-books. Therefore, inasmuch as Mr. Schützenburger and Mr. Barrière added the sodium hyposulphite to the concentrated solution, and then heated the resulted mixture, I believe the precipitation was due to the above action of heat rather than to a precipitation by the sodium hyposulphite. In a 10 per cent. solution of the yttrite group, oxides, I obtained but a slight precipitation with

sodium hyposulphite, which, on re-solution and treatment, did not again precipitate.

Barrière's methods introduce titanium and zirconium, both of which are exceedingly difficult to separate afterwards.

To obtain the pink color of the erbium oxide it must be exceedingly pure. One can easily be misled by the color of these rare oxides when in combination. Some when alone are white, yet when combined are of a dark color, even brown.

In order to obtain a larger sample of "lucium" to work with, I took 1 kilo of an average of several hundred samples of North Carolina monazite sand, carefully following Mr. Barrière's method, making, however, each separation thoroughly, and failed to obtain any earth answering to the reactions of "lucium," only getting as a result less than 1 per cent. of the mixed oxides of the yttrite group of a buff color and very freely soluble in dilute acids.

Since making these experiments, much work has been done by Dr. William Crookes and others to prove that "lucium" is not entitled to a place in the list of elements, but is impure yttrium.

NOTES AND COMMENTS.*

ASPHALTUM IN THE ISLAND OF BARBADOES.

In the Island of Barbadoes, West Indies, says the London *Engineer*, the discovery was made some months back of large quantities of a certain mineral —locally called "manjak"—which bids fair to outrival in point of utility all the similar substances that occur in various parts of the world. Manjak is of a black color, possessing high luster, and having a bright conchoidal fracture, in appearance closely resembling newly-broken pitch. In Barbadoes it is found very near, and sometimes upon, the surface of the ground in seams varying from 1 foot to 2 feet in thickness, running usually at an angle of about 40° and in close proximity to rocks. It is supposed to have been formed by the drying up and consolidation of petroleum, which occurs in abundance in the same localities, and is often seen oozing out of the ground or floating down the streams. In composition it is not unlike Trinidad pitch, the Utah gilsonite and the Canadian albertite, but is of superior quality to any of these. It is supposed to equal the Egyptian asphaltum in quality, but there is a doubt as to the correctness of this view. The analysis of the best quality manjak is: Moisture, 2·00; volatile organic matter, 70·85; non-volatile organic matter, 26·97; mineral matter, 0·18; total, 100·00. As ordinarily met with, however, it does not quite come up to this analysis. It contains rather more—about 5

* From the Secretary's monthly reports.

per cent.—moisture and mineral matter. Referring to the analysis of Trinidad pitch, we find that it contains between 21 per cent. and 30 per cent. moisture, and about 38 per cent. ash, so that the superior richness of manjak in natural bitumen, as compared with Trinidad pitch, is evident. Among the various uses to which manjak has been successfully applied may be mentioned: (1) As insulation for electric wires. (2) As varnishes of the best quality. (3) As bituminous concrete in asphalt roads and pavements. (4) As patent fuel, mixed with peat or other organic matter. (5) In small percentages, as an intensifier of the illuminating power of coal gas. Such satisfactory results have been obtained by its use for insulation that it is expected by some experts that it will soon supplant rubber in all waterproof work.

THE LONGEST BRIDGES.

The longest bridge in the world is that over the Tay, in Scotland, which is 3,200 meters=9,696 feet long; and the next longest is also in Great Britain, being that over the Firth of Forth, 2,394 meters = 5,552 feet in length. The following table gives, in meters and in feet, the lengths of the principal bridges in various countries:

	Meters.	*Feet.*
Tay, Great Britain	3,200	9,696
Forth, Great Britain	2,394	5,552
Moerdyck, Holland	1,470	4,820
Volga, Russia	1,438	4,715
Weichsel, Germany	1,325	4,346
Thoen, Germany	1,272	4,172
Grandenz (Elbe), Germany	1,092	3,580
Brooklyn, United States	488	1,601

The greatest single span of the Forth Bridge is 521 meters = 1,725 feet; of the Elbe Bridge, 420 meters = 1,378 feet; of the East River Bridge, 488 meters = 1,610 feet.

ACETYLENE—PRICE AND COMMERCIAL EFFICIENCY.

In an interesting article by *Julien Lefèvre* (*Revue Scientifique*, March 6, 1897; No. 10, p. 289), read before the French Association for the Advancement of Science, considerable discredit is shown toward the statements of Willson and the works at Spray, N. C., to the effect that the price has been brought to 167.44 francs ($32.18) per tonne (2,240 lbs.), counting hydraulic power at 25 francs ($4.80) per horse-power per year. In Switzerland, where there is an abundance of water-power, this power costs 100 francs ($19.20). As one horse power per hour produces 4 kilograms (8·8 lbs.) of calcium carbide, the cost here becomes about 200 francs ($38.40), and the prices quoted on market are 400 francs for over 1 tonne, or 500 to 550 francs per tonne for less than a tonne. Willson claims that he can produce the carbide for 15 to 25 francs per tonne, while Pictet says that with an improved furnace he can produce absolutely pure carbide at 85 francs per tonne, though this is not as yet realized.

Theoretically, the action of water on 1 kilogram (2·2 lbs.) of calcium carbide should produce 406 grams or 341 liters (or 1 lb. carbide should produce ·308 lbs. or 5·5 cubic feet) of acetylene according to the equation:

$$CaC_2 + H_2O = C_2H_2 + CaO.$$

A good commercial product should yield about 300 liters of gas (or one pound should yield 4·45 cubic feet), at a maximum selling price of carbide of

THE MINERAL PRODUCTION OF THE UNITED STATES IN 1895–'96.

The accompanying table, exhibiting the amounts and values of the various mineral products of the United States in 1895–'96, is from advance sheets of THE MINERAL INDUSTRY, Vol. V, now in press. The *Journal* acknowledges its obligation to the Editor, Mr. R. P. Rothwell, for the privilege of placing the facts thus early before its readers.

MINERAL PRODUCTION OF THE UNITED STATES IN 1895–6.

Compiled for THE MINERAL INDUSTRY, Vol. V.,

By Richard P. Rothwell, editor of the *Engineering and Mining Journal.*

Number.	Products.	Customary Measures.	1895. Quantity. Customary Measures.	1895. Quantity. Metric Tons.	1895. Value at Place of Production. Totals.	1895. Value at Place of Production. Per M. Ton.	1896. Quantity. Customary Measures.	1896. Quantity. Metric Tons.	1896. Value at Place of Production. Totals.	1896. Value at Place of Production. Per M. Ton.
	NON-METALLIC.									
	Abrasives:									
1	Carborundum	Sh. T.	113	102	$67,800	$586.65	595	550	$365,612	$646.65
2	Corundum	Sh. T.	385	349	53,900	154.44	250	227	35,000	153.75
3	Emery	Sh. T.	1,700	1,542	119,000	77.17	1,550	1,406	108,500	77.17
4	Garnet	Sh. T.	877	795	29,465	49.65	2,842	2,578	96,628	37.48
5	Grindstones	Sh. T.	36,380	33,004	290,378	8.79	31,201	28,306	294,338	10.36
6	Millstones				15,925				14,852	
7	Tripoli & inf. earth	Sh. T.	1,783	1,617	26,049	16.00	2,425	2,199	31,928	14.56
8	Whetstones				93,303				105,201	
9	Alum	Sh. T.	117,900	106,959	3,537,000	33.07	77,700	70,489	2,331,000	33.07
10	Antimony ore	Sh. T.	1,083	982	37,905	38.60	150	136	4,750	34.92
	Asbestos and talc:									
11	Asbestos	Sh. T.	664	602	11,837	19.66	716	650	12,670	19.49
12	Soapstone	Sh. T.	22,133	20,097	342,298	17.03	24,319	22,068	265,806	12.05
13	Talc, fibrous	Sh. T.	40,000	36,368	320,000	8.80	45,000	40,824	315,000	7.70
14	Asphalt	Sh. T.	25,525	23,156	170,500	7.36	20,500	19,926	66,900	3.36
15	Asphaltic limestone	Sh. T.	5,550	5,035	16,650	3.31	3,119	2,829	8,714	3.08
16	Bitumin's sandstone	Sh. T.	42,374	38,542	139,945	3.63	53,119	48,180	138,714	2.66
17	Barytes	Sh. T.	20,255	18,371	99,023	5.39	21,500	19,504	86,000	4.41
18	Bauxite	L. T.	18,800	19,100	56,400	2.90	17,096	17,369	68,384	3.93
19	Borax	Lbs.	13,506,856	6,126	742,850	$.12	15,258,014	6,921	762,900	$.11
20	Bromine	Lbs.	394,854	179	102,662	$.57	550,985	249	143,074	$.57
21	Cement, nat. hydraul.	Bbls[a]	7,694,053	1,047,006	4,597,385	4.39	7,454,611	1,014,423	4,353,377	4.29
22	Cement, Portland	Bbls[b]	749,059	135,879	1,430,089	10.52	1,082,654	187,365	1,710,151	9.12
23	Clay, refractory	Sh. T.	3,750,000	3,402,000	4,500,000	1.35	4,000,000	3,628,800	4,800,000	1.32
24	Clay, china	Sh. T.	30,910	28,035	258,431	9.22	29,418	26,688	217,551	8.15
25	Clay, common	Sh. T.			[60,100,000				[65,000,000	
26	Coal, anthracite	Sh. T.	51,897,297	47,081,208	80,250,052	1.71	48,855,563	44,321,768	88,105,837	1.98
27	Coal, bituminous (*h*)	Sh. T.	137,328,600	124,584,506	123,897,958	1.00	138,463,254	125,613,864	115,827,813	.93
28	Coal, cannel	Sh. T.	69,747	63,274	191,804	3.03	54,660	49,587	146,488	2.95
29	Coke	Sh. T.	12,493,464	11,333,996	19,018,276	1.68	10,357,000	9,395,809	17,267,401	1.84
30	Cobalt oxide	Lbs.	6,400	[2,903	8,640	$.30	12,825	[5,817	16,672	$.28
31	Copperas	Sh. T.	14,118	12,805	60,946	5.45	11,170	10,133	52,662	5.19
32	Copper sulphate	Lbs.	45,000,000	20,412	1,750,000	85.73	48,732,840	21,605	1,949,313	90.22
33	Chrome ore	L. T.	1,553	1,578	16,795	10.64	702	713	7,775	10.90
34	Feldspar	L. T.	22,195	22,550	104,082	4.67	22,199	22,554	112,829	5.00
35	Fluorspar	Sh. T.	4,000	3,628	24,000	6.61	4,000	3,628	24,000	6.61
36	Gilsonite (*k*)	Sh. T.	1,150	1,043	34,500	33.12	1,700	1,542	54,500	35.34
37	Graphite, crystalline	Lbs.	377,450	172	17,286	$.05	405,006	184	18,225	9.90
38	Graphite, amorphous	Sh. T.	840	762	4,700	5.17	574	520	3,850	7.40
39	Gypsum	Sh. T.	298,572	270,864	974,219	3.59	231,649	210,152	789,799	3.52
40	Iron ore	L. T.	15,988,000	16,243,808	27,979,000	1.72	14,650,000	14,884,400	28,567,500	1.92
41	Lime	Bbls[c]	[60,000,000	5,443,164	30,000,000	.....	[60,000,000	5,443,164	30,000,000	.....
42	Magnesite	Sh. T.	2,200	1,995	14,700	7.39	2,067	1,875	13,435	7.16
43	Manganese ore	L. T.	170,500	173,337	328,107	1.84	162,526	165,126	339,083	2.05
44	Mica, ground	Lbs.	740,000	335	31,956	95.40	877,000	398	37,711	94.75
45	Mica, sheet	Lbs.	6,200	3	6,400	$1.13	8,000	4	8,405	$2.31
46	Mineral wool	Sh. T.	6,989	6,340	74,962	11.36	5,953	5,400	61,714	11.43
47	Monazite	Lbs.	1,900,000	862	114,000	132.40	17,500	8	875	109.37
48	Natural gas				12,000,000				10,000,000	
49	Paints, mineral	Sh. T.	47,084	42,705	1,086,767	25.45	54,153	49,127	973,268	19.77
50	Paints, vermilion	Sh. T.	118	107	118,190	1105.00	96	87	94,677	1088.25
51	Paints, white lead	Sh. T.	92,939	84,314	8,768,656	104.00	98,068	88,946	7,892,257	90.46
52	Paints, zinc oxide	Sh. T.	22,660	20,498	1,588,300	77.48	16,799	15,240	1,226,925	82.07
53	Petroleum (crude)	Bbls[d]	52,961,943	7,215,896	47,624,913	6.60	61,356,394	8,364,531	56,963,137	6.81
54	Phosphate rock	L. T.	1,098,017	1,015,587	3,296,757	3.25	863,754	877,574	2,591,262	2.93
55	Marls	L. T.	217,700	221,183	587,790	2.67	155,000	157,480	418,500	2.65
56	Precious stones				250,000				200,000	
57	Pyrites	L. T.	107,731	109,088	342,587	3.14	117,782	119,666	297,853	2.49
58	Salt, evaporated	Bbls[e]	12,091,265	1,535,591	5,643,383	3.61	11,156,270	1,416,846	4,828,179	3.41
59	Salt, rock	Bbls[e]	2,184,589	277,443	828,954	2.98	2,198,303	279,184	711,919	2.55
60	Silica, sand & quartz	L. T.	523,640	532,018	553,128	1.04	720,399	732,025	1,076,088	1.46
61	Slate, roofing	Sq'es.	752,606	238,576	2,494,213	10.45	699,100	221,615	2,260,862	10.25
62	Slate, manufactures				392,577				467,575	
63	Soda, natural	Sh. T.	1,900	1,724	47,500	27.56	3,000	2,722	65,000	23.88
64	Soda, manufactured	M. T.		167,000	3,841,000	23.00		158,975	3,656,425	23.00
65	Stone, limestone (flux)	L. T.	4,723,154	4,798,734	1,889,262	.....	4,311,563	4,380,548	1,724,625	.....
66	Stone, marble	Cu. ft			2,888,114				2,600,429	
67	Stone, onyx	Cu. ft	1,200	91	12,000	131.87	3,000	228	24,000	105.26
68	Stone, oölitic	Cu. ft	4,790,422	365,108	1,005,192	2.75	4,040,999	308,111	755,891	2.45
69	Other building stones				26,260,945				27,219,484	
70	Sulphur	L. T.	1,650	1,676	41,250	24.60	2,800	2,845	64,200	22.56
71	Est. prod. unspecified				5,000,000				5,000,000	
	Total non-metals				488,651,351				495,747,553	
	METALS.									
72	Aluminum	Lbs.	900,000	408	495,000	$.25	1,300,000	590	520,000	$.18
73	Antimony	Sh. T.	466	422	70,332	166.42	513	556	85,700	154.32
74	Copper (*m*)	Lbs.	396,453,850	179,894	40,616,300	231.70	467,822,973	212,201	49,729,582	234.35
75	Gold	Ozs. ($)	2,363,612	270,478	46,830,300	$664.60	2,887,965	88,272	58,660,537	$664.60
76	Iron, pig	L. T.	9,446,308	9,597,449	108,632,542	10.77	8,625,127	8,761,130	91,577,610	10.45
77	Lead, value at N. Y.	Sh. T.	156,854	142,298	10,132,768	71.20	174,792	158,571	10,381,843	65.59
78	Platinum	Ozs. ($)	150	$4.66	2,250	482.83	200	$6.21	2,800	450.89
79	Quicksilver	Flks[g]	33,978	1,179	1,313,580	1114.00	33,180	1,151	1,227,660	1066.00
80	Silver, comm'l value	Ozs. ($)	46,331,235	$1,441,087	30,254,296	$20.99	56,222,322	$1,748,710	37,725,178	21.57
81	Zinc	Sh. T.	81,858	74,245	5,942,890	80.04	77,637	70,432	6,074,219	86.24
	Total metals				244,290,167				255,985,229	
	Grand totals									

(*a*) Barrels of 300 lbs.; (*b*) 400 lbs.; (*c*) 200 lbs.; (*d*) 42 gals.; (*e*) 280 lbs. (*f*) Troy ounces. (*g*) Flasks of 76½ lbs. (*h*) Bituminous coal includes brown coal and lignite. The anthracite production is the total for Pennsylvania, Arkansas, and Colorado. (*i*) Estimated. (*j*) Kilograms or per kilogram. (*k*) Including bitumen from Texas. (*m*) The value of the copper production is calculated at 0.25c. per lb. less than the average price of Lake copper at New York.

Abbreviations: Sh. T., short tons (2000 lbs.); L. T., long tons (2240 lbs.); M. T., metric tons (2204.6 lbs.); Sq'es, squares (100 sq. ft. lapped and laid).

500 francs per tonne. If we then compare in the following table the price of other illuminants we see that the price of acetylene is not so very great when all things are considered :

COMPARISONS OF VARIOUS ILLUMNANTS.

	Price Francs.	Consumption per Carcel-hour.	Price in Francs per Carcel-hour.
SOLIDS AND LIQUIDS, PER KILOGRAM (2·2 lbs.).			
Wax candle (de l'Etoile)	2·40	80 gr'ms.	0·1920
Colza oil	1·30	45 "	0·0585
Petroleum oil	0·75	30 "	0·0225
ILLUMINATING GAS, PER CUBIC METER.			
Butterfly and Manchester Burners	0·30	137 liters.	0·0411
Benzol Burners, 30 to 40 jets		105 "	0·0315
Wenham-Star Burner		100 "	0·0300
Parisian and Industrial Burners		50 "	0·0150
Welsbach Burner		20 "	0·0060
ELECTRICITY, PER KILOWATT-HOUR.			
Arc Light, round globe, average	1·10	0·011 K. W.	0·0121
Incandescent Light		0·034 "	0·0380
ACETYLENE GAS, PER CUBIC METER.			
Violle Lamp	1.80	5·56 "	0·0100
Burners of small delivery		8·00 "	0·0144

1 gram = 0·0022 lbs.; 1 cubic foot = 28·3 liters ; 1 k. w. = 1·34 horse power ; 1 cubic meter = 35·3 cubic feet ; 1 franc = 19·2 cents. [*Progressive Age.*

TECHNICAL BREVITIES.

To lessen the danger from *acetylene* in common use, it has been proposed *to store it in solution*. Messrs. Claude & Hess propose, for this purpose, acetone, which, at the ordinary pressure and a temperature of 60° F., is capable of absorbing 300 times its volume. That is, 1 pound of acetone is capable of storing practically all the acetylene that will be generated from 1 pound of calcium carbide.——Mr. C. J. Reed, in a recent impression of the *American Electrician*, discusses the subject of *the direct production of electricity from fuel*, with incidental reference to the recently mooted processes of Jacques and Case. The author's views are pessimistic. He holds that the practical solution of the problem will depend on the discovery of new chemical elements, having properties radically different from those of any known substances.——Spring has observed that two well-polished and clean *aluminum surfaces*, brought together under pressure, and kept for eight hours at a temperature of about 625° F., *will adhere as though soldered*.——Dessing has succeeded in producing *electrode carbons*, which are claimed to fully solve all the difficulties heretofore met with in using carbon electrodes in electro-metallurgical work. The new carbons are of unusual hardness, exhibit a crystalline structure, and are remarkable for purity and high conductivity. ——Zakorski refines impure *bismuth* electrolytically, using the impure metal as anode in an electrolyte of nitric acid. For cathode, pure bismuth, carbon

or platinum is used. The pure metal is separated on the cathode, from which it may readily be removed and collected. It is then washed with dilute nitric acid, rinsed and fused.—The authorities of the General Italian Exhibition, to be held in Turin, 1898, announce a "*Galileo Ferraris Prize*," of 15,000 francs, to be granted for the most important application of electricity to industrial uses. The prize is open to international competition.

ELECTRIC RAILWAYS IN EUROPE.

Mr. Thomas Ewing Moore, commercial agent for the United States at Weimar, Germany, has submitted to the State Department, Washington, an interesting report concerning electric railways in Europe. He states that electric locomotion is gradually gaining ground in the various European countries, though not to the same extent as has been the case in the United States During the year 1895 the total number of electric railways or tramways in Europe rose from 70 to 111; the length of lines from 435 to 560 miles, and the output of the "centrals" from 18,150 to 25,095 kilowatts, while the number of cars increased from 1,236 to 1,747.

The mileage of electric railways in the principal European countries is as follows: Germany, 252 miles; France, 82 miles; Great Britain and Ireland, 66½ miles; Austria-Hungary, 44 miles; Switzerland, 29 miles, and Italy, 24¾ miles. Servia, Russia, Belgium and Spain have but from 6¼ miles to 18½ miles, while the remaining countries have less than 5 miles each.

Of these 111 lines 91 are operated on the overhead surface system, 12 on the underground system, and 8 by means of accumulators. It is estimated that the new lines projected for the present year will exceed in number and mileage those constructed during any previous year. Considerable activity exists in planning and laying out new routes.

The capital invested in electric lines in Germany alone is estimated at $23,800,000. German electrical companies and supply manufacturers have greatly increased in number and capital during the past few years. Berlin is about to introduce general electric locomotion in its streets, and the electric street railways in Hamburg and Leipsic are about completed.

The overhead system, Mr. Moore states, will be preferred for the lines contemplated, or in course of construction, on account of its cheapness.

BOOK NOTICES.

Encyclopédie des Aide-Mémoire. Librarie Gauthier.—Villars et Fils. Paris (Small 8vo. Price per volume, 2.50 francs, unbound; 3 francs, bound.)

Since our last notice of this condensed series of technical subjects, the following additional volumes have appeared, As previously noticed, each of these volumes treats of a special subject, and is substantially complete in itself:

Henriet (*H.*), ancien Élève de l'École de Physique et de Chimie industrielle de la Ville de Paris, Chimiste à l'Observatoire de Montsouris. Les gaz de l'atmosphère.

Vallier (*E.*), Chef d'gscadron d'Artillerie, Correspondant de l'Institut. Projectiles de campagne de siège et de place. Fusées.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage aux gaz, aux huiles, aux acides gras.

Loppé.—Accumulateurs électriques.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage électrique.

Urbain (*V.*), Ingénieur des Arts et Manufactures, Répétiteur à l'École Centrale. Les succédanés du chiffon en papeterie.

Fabry (*Ch.*), ancien Élève de l'École Polytechnique, Maitre de conférences à la Faculté des Sciences de Marseille. Les piles électriques. W.

Hydraulic Cement: its properties, testing and use. By Frederick P. Spalding. New York: John Wiley & Sons. London: Chapman & Hall, Limited. 1897. 12mo, cloth, $2.

This volume should prove of much practical value to engineers engaged in construction work, requiring the use of hydraulic cements. It presents, in condensed and readily comprehensible form, the most recent views respecting the nature and properties of these materials, and a discussion of the merits of the various methods of testing cements that are in vogue. An appendix contains a number of sample specifications used by prominent railway companies, municipal bureaus, etc. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 16, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 16, 1897.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 37 members and visitors.

Additions to membership since last report, 12.

In reference to the preamble and resolutions bearing on the abatement of the smoke nuisance, referred by the Institute at its last stated meeting to the Board of Managers, with the request that the Board would report on the expediency of their adoption, the Actuary reported that the Board had adopted the following resolutions at its stated meeting of June 9th, viz.:

Resolved, That in view of the importance of the subject and the necessity of having any deliverance by the Franklin Institute carefully considered, the Board of Managers recommend that formal action be deferred until every member of the Institute shall have had the opportunity of reading the discussion as it will appear in the *Journal*.

Resolved, That the Board will present resolutions covering the subject, with its recommendations, to an early meeting of the Institute.

Mr. Howard Murphy, civil engineer, read a paper entitled: "A General System for the Sewerage of Suburban Philadelphia." Referred to the Committee on Publications, with the view of placing in type for distribution to members for discussion at the stated meeting of September 15th.

Prof. George A. Hoadley, Swarthmore College, presented an informal communication on "Observations Relating to Thunder Storms," illustrated with several lantern slides. Referred for publication.

A communication from Col. C. Walseley Cox, on the "Hutchinson Smoke-Consuming Furnace," was deferred on account of the illness of Col. Cox.

The Secretary's report embraced a reference to the industry of mining monazite for the production of the rare earths used in the manufacture of the mantles for the Welsbach incandescent light. Also, an explanation of, and experimental demonstration with, the Burton Electric Liquid Forge.

Action on the election of a successor to the late John H. Cooper, on the Committee on Science and the Arts, and on this Committee's report of the record in the case of the Shaw gunpowder tester, was postponed until the stated meeting of September 15.

Prof. Joseph W. Richards was appointed as the delegate of the Institute to the Seventh International Geological Congress, about to meet in St. Petersburg, Russia, and the Secretary was directed to provide Professor Richards with the needful credentials.

The Secretary was further directed to ascertain whether the name of the Institute was being used in an unauthorized manner for the purpose of obtaining an appropriation of money from the Legislature of the State of Pennsylvania, and in such case to make such explanations and corrections by correspondence as the facts would appear to warrant.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held June 1, 1897.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects passed first reading:

The Phantascope, C. Francis Jenkins, Washington, D. C.

All-Wrought Steel Pulley, Thomas Corscaden, Philadelphia, Pa.

Rochester Time Recorder. Willard & Frick Manufacturing Company, Rochester, N. Y.

Reports on the following subjects were adopted:

Typewriting Machine.—John L. Williams, New York.

ABSTRACT.—This is a keyboard type-bar machine, having the type-bars divided into two groups, before and behind the platen, at the top of the machine, the types striking the platen and printing on top. The movement of the type-bar is similar to that of the upper limb of a parallel ruler, set on edge and carrying a type on the end of the upper limb, resting on an inked pad

when in position, as if the two limbs were together, and striking the platen when extended.

Each type-bar (of which there are twenty-eight) carries three letters or characters, as may be, and the platen has two shafts, bringing all of them (eighty-four) into action. The paper passes down on both sides of the platen, and is rolled in cradles provided for it on both sides.

The printing is in full view of the operator, and is done directly from the type, which gives to the printing a sharpness not attainable with the usual method of printing through a ribbon. Protected by U. S. Letters-Patent, No. 523,028, July 17, 1894; No. 501,753, July 18, 1893; No. 442,697, December 16, 1890.

The report considers some eighteen claims of merit adduced by the applicant, and finds that the greater number of these are more or less completely substantiated. The John Scott Legacy Premium and Medal is recommended. [*Sub-Committee.*—G. M. Eldridge, Hugo Bilgram, J. Logan Fitts, Wm. C. Head.]

Method for the Trisection of the Angle.—Charles Morrell, Chicago, Ill.

ABSTRACT.—Applicant submits a general method for the trisection of an angle. The sub committee charged with the investigation applied the method described by applicant to angles selected at random, and found it to be incorrect by analytic and graphic methods. [*Sub-Committee.*—L. F. Rondinella, Edwin S. Crawley, Edgar Marburg, Hugo Bilgram.]

Gear-Moulding Machine.—Samuel Groves, Pittsburgh, Pa.

ABSTRACT.—This machine belongs to the type of gear-moulding machine introduced some twenty-five years ago by Craven Bros., of Manchester, England, and subsequently modified by various inventors, notably by Walker (1881), and Kepp (1890). They consist, generally speaking, of a revolving table for carrying the flask, and a swinging arm supported on a column or bracket at one side of the table for carrying the pattern sections and sweeps. The table is provided with devices for centering and leveling the flask, and for rotating it intermittently, to space the teeth of the wheel to be moulded. The swinging arm is provided with an adjustable pattern holder at its outer end, and can be swung out of the way when the flask is to be removed. It is in the mechanical details of a machine of this class that the applicant claims to have made improvements. For these the reader is referred to applicant's U. S. Letters-Patent, No. 573,783, December 22, 1896.

The report finds that Mr. Groves' improvements involve few elements of novelty, and that they are of minor importance, some of them being of the nature of refinements in mechanical details that will be of doubtful utility in a machine to be exposed to the dust, dirt and rough usage prevailing in the foundry. [*Sub-Committee.*—Thos. P. Conard, J. Sellers Bancroft.]

Flying Machine.—Praull Aëromotor Company, Philadelphia.

ABSTRACT.—The basis of this machine is a differential piston engine by which the power is applied directly to screw-vanes, and by which a differential movement of the vanes is produced, (*i. e.*, a quick revolving down-stroke and a slow up-stroke), to secure the same effect as that of the wing of a bird when flying. The vanes are set opposite each other at the forward and rear ends of the car to be propelled. Applicant submits a crude and inoperative model, with which the committee is unable to make a demonstration. In

view of this fact the report finds that the inventor has failed to sustain his claims. [*Sub-Committee.*—Wm. M. Barr, John H. Cooper, Tinius Olsen.]

Automatic Safety Device for Electric Circuits.—Lewis G. Rowand, Camden, N. J.

ABSTRACT.—This invention is intended to be an improvement in automatic safety devices for electric circuits, and is claimed to be particularly adapted to cut off the current from a section of a trolley line, which, from any cause, may become broken, or from which it is desirable to cut off the current, as in the case of a fire. The system will be found fully described and illustrated in the *Journal* (*vide* J. F. I., Vol. CXLIII, p. 357, *et seq.*, May, 1897). The system is protected by U. S. Letters-Patent, No. 570,852.

The finding of the report is to the effect that the apparatus accomplishes all that is claimed for it, and that the combination of devices for the purposes named has not been anticipated. It is believed, however, that the cost of properly equipping a trolley road with the Rowand devices would be prohibitive. For the general merit of the device, the Edward Longstreth Medal of Merit is awarded. [*Sub-Committee.*—E. A. Scott, C. H. Bedell, C. W. Pike.]

Automatic Fluid-Pressure Friction-Clutch.—George M. Richards, Erie, Pa.

ABSTRACT.—The purpose of this invention is to facilitate the transmission of motion from one shaft to another, performing in this operation the same function as is performed by the numerous friction-clutches at present in use. The Richards device is an improvement upon the fluid friction-clutches of Brayton (1880) and Jones (1890).

Following is a brief general description: On the shaft to be driven is secured a flange, which is enclosed by a shell or housing, to which latter is secured the driving pulley. The frictional contact necessary to communicate motion from the housing and driver to the friction flange and shaft is obtained by means of fluid pressure forcing the housing and friction flange together, the friction being automatically produced by a pump, which is operated through the relative difference of motion of the two main parts of the clutch, viz.: the friction flange and the housing. For specific details the reader is referred to applicant's U. S. Letters-Patent, No. 574,823, January 5, 1897.

The report finds that the invention displays much ingenuity, and especially commends as meritorious that feature of its operation by which the friction is automatically increased as may be needed. This favorable opinion is qualified, however, by the statement that it is complicated and costly, liable to become disarranged, and, when out of order, difficult to repair. It is admitted, however, notwithstanding these objections, that there may be situations where the Richards Clutch could be used with advantage.

For the ingenuity displayed in making the friction-clutch automatic in action, which appears to be original with this invention, the Edward Longstreth Medal of Merit is awarded. [*Sub-Committee.*—Tinius Olsen, Wm. M. Barr, Thos. P. Conard.]

Metallic Corner Bead.—Edward B. Marsh, Lexington, Mass.

ABSTRACT.—This is a device for protecting the corners of wall plastering, and is substantially a metallic substitute for the common rounded wooden corner-bead in general use. It is formed of rolled metal with a rounded edge and provided lengthwise on either side with one or more recesses into which the plaster may flow and permit effectual contact. The bead piece is supported

by clips of flat metal, formed by slitting one end, thus making two ends. These are bent so as to embrace the corner bead by entering the recesses in its side. The other end of the metal strip is provided with holes by which it is secured to the studding with nails.

The report finds the invention to be a practical and inexpensive means of accomplishing its intended purpose of providing a substantial and neat metal corner bead, which will render the plaster less liable to be chipped or broken at the point of union. Protected by U. S. Letters-Patent No. 562,783, June 23, 1896. The invention is commended for simplicity, practicability and durability. The Edward Longstreth Medal of Merit is awarded. [*Sub-Committee.*—H. R. Heyl, Chas. A. Hexamer.]

Investigations on the Molecular Physics of Cast Iron.—Alex. E. Outerbridge, Jr., Philadelphia.

ABSTRACT.—These investigations have their origin in the observation made by the author that certain test bars of cast iron exhibited unexpected deviations from the strength which they were expected to exhibit. The only assignable cause for the abnormal (increased) strength of these pieces, which came to light in the examination of the facts of the case, was the fact that these specimens—contrary to the usual custom—had, previous to testing, been cleaned in a tumbling barrel.

The outcome of these observations was a carefully conducted series of experiments to determine the influence of vibration on cast iron. Experiments with a number of test bars cast from one pattern and one runner, some cleaned in the tumbling barrel and others with a wire brush, showed that those which had been subjected to concussion in the mill, were from 10 to 15 per cent. stronger than the others.

It occurred to the author that this increase in strength might be due to the "mobility of cast iron at ordinary temperatures when subjected to repeated shocks." To test the correctness of this hypothesis, a number of newly cast test bars were subjected to 3,000 taps from a hammer upon one end. When these were compared for strength with other untreated bars from the same set, they showed the same proportionate increase of strength as had been observed with the bars cleaned in the tumbler. Numerous other experiments confirmed the fact that a substantial increase of strength, amounting in some cases to as much as 35 or 40 per cent., was exhibited by specimens of cast iron when subjected to preliminary repeated shocks.

Mr. Outerbridge has formulated the results of his scientific study of these phenomena in the statement that the molecules of cast iron are capable of movement without the necessity of heating the mass (as in ordinary annealing) and that by the methods above described, a species of "molecular annealing may be effected in cast iron at the ordinary temperature, which will release the strains in the castings, precisely as does annealing by slow cooling in heated ovens or pits." (For a detailed account of the author's experiments and conclusions, the reader may refer to the *Transactions* of the American Institute of Mining Engineers, for the year 1896, and this *Journal*, Vol. CXLII, p. 148, August, 1896.)

The report finds that while it has long been known that a certain molecular change takes place in cast iron in the course of time, and that this change tends to relieve the internal strains and render the casting tougher,

Mr. Outerbridge has been the first to make a careful study of the phenomena, and to note that this change may be hastened by impact, and the whole effect produced in a short time.

The award of the John Scott Legacy Premium and Medal is recommended. [*Sub-Committee*—C. J. Prince, Wm. C. Henderson.]

Screens for Photo-Mechanical Engraving.—Louis E. and Max Levy, Philadelphia.

This invention relates to certain improvements in the manufacture of screens or gratings used in the production of half-tone printing blocks by photography. In the production of such half-tone engravings, the requisite grain in the negative is obtained by interposing a screen between the lens of the camera and sensitive plate. The improvements of the Messrs. Levy consist: (*a*) in a radically new system of ruling such (glass) screens or gratings; and (*b*) in a new method of mounting the screens to protect them from injury.

The earliest gratings for this purpose (by v. Egolfstein & Sartain, in 1861) were made by photography, and were lacking in sharpness of line. The Messrs. Levy corrected this defect by ruling through a ground laid upon plate glass, etching the lines thus laid bare, and, after cleaning off the remaining ground, filling the lines so etched with an opaque pigment. Two such glass plates are placed together face-to-face, so that the lines on one cross the lines of the other at right angles, the surfaces bearing the etched gratings being in the center of the system. They are thus not only in the same plane, thus insuring the maximum of sharpness, but also are completely protected from injury by the glass plates forming the outer surfaces of the combination. A pair of such glasses is cemented together with Canada balsam, and when thus finished, constitutes the completed screen.

The second improvement of the Messrs. Levy relates to the character of the lines of the grating and to the graduated photographic effects obtainable from the intersections of the two ruled plates. (For the details of this mode of ruling the reader is referred to the report and to the patent specification.)

The report commends these improvements highly, and refers to the fact that the "value of the improvements of the Messrs. Levy has been widely recognized by the workers in half-tone, and have given a world-wide renown to the Levy screens; so that now nearly every photo-engraving establishment in both America and Europe employs them."

The improvements above referred to are covered by U. S. Letters-Patent No. 492,333, February 21, 1893, and No. 521,659, June 19, 1894.

The award of the John Scott Legacy Premium and Medal is recommended to the inventors. [*Sub-Committee.*—D. Anson Partridge, Samuel Sartain, Hugo Bilgram, Coleman Sellers, John Sartain.]

CHEMICAL SECTION.—Stated meeting, Tuesday, June 15, 8 P.M.

The meeting was devoted to a lecture by Prof. Joseph W. Richards, Lehigh University, Bethlehem, Pa., President of the Section. *Subject.*—"A Critical Review of Methods of Determining Minerals." (Referred for publication in full.)

ELECTRICAL SECTION.—No meeting.

SECTIONS.

MINING AND METALLURGICAL SECTION.—Stated meeting Wednesday, June 9th; Mr. Benjamin Smith Lyman, President, in the chair.

Mr. H. B. C. Nitze, Chemist to the Wetherill Concentrating Company, Bethlehem, Pa., presented a paper "On Monazite," giving its chemical and mineralogical characteristics, occurrence (chiefly in North Carolina and Brazil) and industrial application for manufacturing the rare earths used in the production of the mantles for the Welsbach light. The interesting fact was noted that the annual production of this once so-called rare mineral now exceeds 1,000,000 pounds. The finding of the mineral naturally concentrated in sea-beach deposits on certain portions of the Brazilian coast, whence it is shipped as ballast, has so greatly reduced the price, that the mining of the mineral in North Carolina has been abandoned as unprofitable. The paper was illustrated by an exhibit of the salts of the rare earths produced from monazite, shown by Mr. Waldron Shapleigh, chemist to the Welsbach Light Company.

Mr. Charles James, superintendent of the steel department of Henry Disston & Sons, described "A Special Process for Treating Cast Iron." White iron, with approximately 2·40 per cent. combined carbon and 0·4 per cent. graphitic carbon, is used for the purpose. The castings are placed in a muffle furnace, in which they are subjected to the action of a secret composition (said to be a powerful, volatile oxidizing agent) and maintained at a temperature slightly below fusion for five or six hours. The product may be forged and tempered and shows a remarkable increase in tensile strength. The total carbon in the product seems to be the same as in the untreated iron, but combined carbon has been substantially altered into a finely disseminated uncombined carbon. Doubts were expressed in the discussion which followed, whether the result was not due entirely to the annealing, rather than to the "medicine." The prolonged annealing was thought to be a sufficient explanation of the facts. The process is in commercial operation in a large foundry in Philadelphia, producing hatchets, hammers, etc.

Dr. D. K. Tuttle, melter and refiner at the U. S. Mint, in Philadelphia, gave an informal account of an examination he had been officially called on to make in connection with an alleged discovery of a process of transmuting base metal into gold. The investigation proved the fallacy of the alleged discovery, but disclosed the interesting circumstance that practically all the product sold as "pure" antimony by the best-known chemical houses, contains distinct traces of gold.

The Section adjourned over the summer recess, to reconvene on September 8th, when Capt. Zalinski will lecture on "Japanese Swords," illustrating the subject with the aid of his large and valuable collection of these remarkable products of the metallurgical art.